

UNITED STATES AIR FORCE RESEARCH LABORATORY

The Effects of Noise on Birds of Prey: A Study of Peregrine Falcons (*Falco peregrinus*) in Alaska

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PREFACE

Robert C. Kull, Jr. and Elizabeth Pruitt

In the mid-1980s the U.S. Air Force (Air Force) established the Noise and Sonic Boom Impact Technology (NSBIT) Advanced Development Program Office. NSBIT's task was to compile and summarize the decades of noise and sonic boom research and to identify gaps in the scientific literature. After a careful review of existing literature on the effects of noise on wildlife (Kull and Fisher 1986, Awbrey and Bowles 1990), a preliminary model to predict the effects of aircraft noise on raptors was built (Bowles et al 1990). In 1993, at the request of the Air Force's Armstrong Laboratory (now the Air Force Research Laboratory), the Strategic Environmental Research and Development Program approved funding for a field research project to test this model. The proposal suggested that the study be conducted on the effects of military jet noise on Peregrine Falcons in Alaska. At the time the research was conducted, Peregrine Falcons were a federally listed endangered species; the number of breeding pairs in Alaska was high and increasing; there was an historical database of central Alaskan peregrine population; and, overflight support from Elmendorf Air Force Base and the Alaskan Air Command was available.

In 1994, a feasibility study was performed and it was determined that: military jet aircraft could be directed over peregrine eyries; peregrine responses to military jets could be observed; noise levels of aircraft could be recorded; and, population-level effects could be predicted based on acute responses of Peregrine Falcons to jet aircraft overflight. This preliminary study as well as the resulting multi-year field study was a cooperative effort between the Air Force, U.S. Fish and Wildlife Service, Alaska Biological Research, the University of Alaska at Fairbanks, and Oregon State University.

Surveys of potential Peregrine Falcon nest sites were conducted from helicopters and boats during the breeding seasons in 1995, 1996, and 1997 beneath military training airspace along the Yukon, Tanana, and Porcupine Rivers and their tributaries in east-central Alaska. Occupancy, nesting success, and productivity of peregrines were monitored. Noise levels at individual eyries were recorded with Animal Noise Monitors (ANMs) which were deployed at nest sites.

The study examined Peregrine Falcon responses to animate and inanimate disturbances and the relationship between these responses and nesting success. Response to military jet overflights and other disturbances by adult Peregrine Falcons were recorded by direct observation in the field. Only two percent of responses to military jet overflights were considered intense (flight responses). Males tended to respond more intensely to jet overflights than females. The data suggested that peregrines were more

sensitive to humans and other raptors than to disturbances by helicopters, jets and boats. Variation in intensity of response suggested that differences in sensitivity among individual peregrines, possibly related to experience, are more important in predicting response than level of exposure to noise. Nest productivity did not differ between nests that were overflowed and those that were not; however, average response of peregrines was negatively correlated with productivity. This indicates that intensity of response is a better indicator of productivity than noise exposure.

The study also examined the effects of military jet overflights on nest attendance, time-activity budgets, nestling provisioning rates, nest success and productivity. Observations indicated that ledge attendance in peregrines decreased with increasing age of chick, that parents compensate for larger broods by delivering larger prey rather than increasing per nestling prey delivery rates. At nests sites exposed to jet overflights, male ledge attendance was somewhat decreased but was compensated for by increased attendance by females. Frequently performed activities and nestling provisioning rates were not influenced by exposure to jet overflights. No differences were observed between periods with overflights and those without at the same nest. There was not a significant effect of exposure to jet overflight on nest success or productivity.

The following chapters describe these studies in detail.

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CHAPTER 1

INTRODUCTION: PROJECT SCOPE, STUDY AREA, NATURAL HISTORY, AND HISTORICAL STATUS OF PEREGRINE FALCONS (*FALCO PEREGRINUS ANATUM*) IN EAST-CENTRAL ALASKA

Robert J. Ritchie & Daniel D. Roby

PROJECT SCOPE

This report is a synthesis of the various components of a three-year research project designed to assess the effects of low-altitude jet aircraft overflights on the behavior and nesting success of Peregrine Falcons. The study was originally developed by the Alaska Cooperative Fish and Wildlife Research Unit (U.S. Geological Survey) and ABR, Inc., in cooperation with the U.S. Fish and Wildlife Service, Alaska Department of Fish and Game, and the 11th Air Force. This project was developed to perform field studies to assess effects of jet aircraft overflights on parental behavior and productivity of nesting Peregrine Falcons (*Falco peregrinus anatum*) in east-central Alaska. The study design takes into account such factors as variation in the intensity and frequency of potential overflight disturbance, stage of the nesting cycle, parental care behavior, prey provisioning rates to nestlings, weather conditions, and habituation as they influence responses to overflights by nesting Peregrine Falcons and associated changes in nesting success.

The U. S. Air Force (USAF) currently maintains low-altitude Military Training Routes (MTRs) and Military Operations Areas (MOAs) in east-central Alaska. These sparsely settled areas include breeding territories for many raptors, including Peregrine Falcons, Bald Eagles (*Haliaeetus leucocephalus*), Osprey (*Pandion haliaetus*), and Red-tailed Hawks (*Buteo jamacensis*), among others. Peregrine Falcons were selected as the study species for several reasons: (1) the species was listed as threatened by the Endangered Species Act at the time of the study, as well as throughout the Lower 48 States, and is therefore a species of special concern for National Environmental Policy Act (NEPA) compliance, (2) the response of this species to disturbance near the nest is pronounced, (3) breeding pairs are highly philopatric and repeatedly use particular nest sites each year; (4) nests are limited to river bluffs and rock outcrops, and are thus readily located, (5) most nest sites located on river bluffs are readily observable from across all or part of the river, (6) Peregrine Falcons are not dependant on cyclic prey that are subject

to large population fluctuations, such as microtine rodents, snowshoe hares, ptarmigan, or grouse, as are several other species of raptors in interior Alaska, and (7) many active nest sites in interior Alaska are known and data on productivity of Peregrine Falcons at these sites have been collected since 1976.

The Environmental Impact Assessment Process (EIAP) was initiated in 1972 with the passage of the National Environmental Policy Act (NEPA). As a part of this process, U.S. government agencies are required to prepare Environmental Assessments (EAs) or Environmental Impact Statements (EISs), which are reviewed by the U.S. Fish and Wildlife Service (USFWS) when threatened or endangered species or their habitat is potentially affected. The United States Air Force (USAF) has historically been required to document the effects of aircraft activity on animal populations, and the Noise and Sonic Boom Impact Technology Program (NSBIT) was formed specifically to study the potential effects of aircraft noise. Many of the assessments accomplished to date contain unsubstantiated assertions concerning the effects of aircraft noise on wildlife. Prior to 1989 noise studies on wildlife were not well controlled or planned. In 1989 the USAF began performing several 3-4 year studies on the effects of aircraft noise on wildlife species. These studies are beginning to prove useful for environmental planners to predict the impact of maintaining or expanding low-altitude Military Training Routes (MTRs) and Military Operations Areas (MOAs).

Due to issues raised during public scoping meetings and documented comments from the USFWS and the National Park Service (NPS), there is concern that aircraft overflights may disturb nesting raptors and negatively affect their productivity. Raptors are of particular concern for several reasons. First, as higher order consumers they serve as indicators of environmental conditions. Second, within the last 30 years, many raptor populations have experienced dramatic declines, with Peregrine Falcons and Bald Eagles listed as threatened or endangered. Finally, nesting raptors are known to be sensitive to human disturbance (Steidl and Anthony 1995, Fyfe and Olendorf 1976).

Quantitative and consistent predictions about the possible effects of aircraft activity on reproductive success and population stability cannot be made without valid predictive models of the relationship between levels of disturbance and negative effects on reproduction. The USAF embarked on a project in 1989 to review the current literature regarding the effects of low-altitude jet aircraft overflights on raptors and to develop an interim model to predict the effects. The interim model was published in 1990 (Awbrey and Bowles 1990), but because the model was purely hypothetical, various assumptions and hypotheses incorporated in the model needed to be tested with empirical data. The authors of the model admitted that theirs was largely a "straw man" model that makes "worst-case" predictions (Awbrey and Bowles 1990).

Nevertheless, the model has been integrated into the Assessment System for Aircraft Noise (ASAN), as part of NSBIT because of the strong need for a predictive model.

In the process of developing the model, Awbrey and Bowles (1990) identified several weaknesses in previous research on the effects of aircraft overflights on reproductive success of raptors. No studies to date had included low-altitude military operations and also specifically examined the correlations between disturbance variables, raptor behavioral responses, and reproductive effects. As of 1990, when the model was developed, only nine studies had looked at the effects of aircraft overflights on raptors. Three major and recurrent problems with these studies were: (1) small sample sizes, (2) inadequate data for the most critical periods of the nesting cycle, early incubation and fledging, and (3) a lack of quantified sound-level data (Awbrey and Bowles 1990).

The one study that included low-altitude military operations (Ellis 1981) had several weaknesses (Awbrey and Bowles 1990). Like most other studies, sample sizes were small (four experimental sites for two years, nine control sites). An additional problem was uncontrolled disturbance; the "unexposed" group was exposed to approximately one low-altitude overflight or sonic boom per week. It has not been demonstrated that the relationship between rates of exposure and nesting success is negative and linear, so it is possible that the control group was actually subjected to another, possibly more severe, type of treatment (i.e., higher rates of exposure could hasten habituation and lessen the effects of disturbance). Another problem was that no attempt was made to determine if reoccupancy of nest sites in the second year of the study was the result of the same individuals returning. If this were the case, then the amount of disturbance at the sites was not enough to cause long-term abandonment of nest sites. If new individuals occupied the sites, however, this could not be demonstrated.

Disturbance could cause a decline in nesting success through several mechanisms. Desertion; injury to eggs or young by frightened adults; cooling, overheating, and loss of moisture from eggs; exposure of nestlings; missed feedings; and premature fledging are some of the potential effects of human intrusion on nesting raptors that could also result from aircraft disturbances (Fyfe and Olendorff 1976). Steidl and Anthony (1995) found that prey consumption rates by Bald Eagle nestlings decreased with proximity of human recreational activities. Peregrine Falcon eggs and young could be particularly vulnerable to injury when disturbed parents flush from the nest (Fyfe and Olendorf 1976). The primary concern by the USFWS regarding effects of military overflights on raptors is the potential for a startle effect (R. Ambrose, pers. comm.). Peregrine Falcons incubate and brood with their feet beneath eggs and chicks, and have been observed to kick an egg out of a nest scrape when frightened (Cade 1960). Such startle responses could be elicited either by the sudden appearance of aircraft very close to the nest site or by

sonic booms. Violent startle responses that result in direct mortality of eggs or young may be rare and difficult to quantify, but could result in significant declines in productivity for a population as a whole. When birds are habituated to a disturbance, however, they do not flush as readily, suggesting that birds react more strongly to novel stimuli, leading to a decrease in vulnerability with experience (Awbrey and Bowles 1990).

One hypothesis is that as the breeding season progresses, parents become more defensive towards intrusions because of current investment in offspring. Dawkins and Carlisle (1976) argued that it is not the level of previous investment, but rather the remaining level required to insure survival of young past vulnerable periods that dictates their willingness to risk their own lives in defending offspring. To maximize fitness, adults must assess (consciously or unconsciously) the additional investment required to insure survival of young to reproductive age. For instance, if an adult is faced with a threatening situation, the parent must "decide" whether to defend the nest to the death, abandon the nest immediately, or attempt some intermediate level of defense. If it is early in the nesting cycle, the level of future investment required is high and birds are more apt to abandon in order to increase the potential for future reproduction, rather than risking possible injury or death. Later in the season, when relatively little effort is required to achieve completion of a successful breeding season, adults have more to gain by defending.

Knight and Temple (1986) present an alternative hypothesis for the observed increase in nest defense late in the season, suggesting that increased defensive reactions are the result of researcher methods. Repeated visits may positively reinforce defensive behavior and the loss of fear in parents, which leads to increased levels of defense. Montgomerie and Weatherhead (1988) reviewed the adaptive hypotheses for explaining inter- and intra-specific variation in nest defense behavior. They suggested that a comprehensive theory to explain various patterns of nest defense must be based on differences in life-history traits, such as parental experience; offspring number, quality, and vulnerability; and nest accessibility and apparency. This suggests that parents that are prone to leave the nest during disturbance do so because of lower "reproductive commitment" (due either to inexperience or low prey availability), and may be less productive even in the absence of disturbance.

Bowles et al. (1990) identified several avenues of future research that would be helpful for understanding the effects of aircraft overflights on reproductive success of raptors. First, they used theoretical habituation functions in their model to scale the probability of response by nesting raptors to overflights. The actual shape and slope of these functions is unknown for nesting raptors. It is also not known whether nesting raptors habituate to all types of disturbance; increased sensitivity may develop toward certain stimuli (e.g., sonic booms) that elicit startle responses or are followed by negative reinforcement. Second,

the baseline response of naive birds to overflights (starting point for habituation functions), and the relationship of naive response to phase of the nesting cycle, are unknown. Finally, the core of the Bowles et al. (1990) model is based on the hypothetical assumption that 10% of total productivity (number of young fledged) is lost if nests with eggs or young are exposed to approaches of < 150 m or sound levels > 95 dB 100 times. The authors acknowledge that the threshold for effects adopted in their model is hypothetical, but that it represents a "conservative" and "worst-case" approximation. Actual measurements of per incident loss rates are needed for a variety of raptor species under a variety of field conditions.

Several relationships need to be explored and quantified to improve the present model (Awbrey and Bowles 1990). The relation between disturbance and reproductive effects must be quantified directly, and it should be determined whether magnitude of disturbance or raptor behavioral response to disturbance is the best predictor of these effects. The dosages of aircraft activity or noise that cause or are correlated with reproductive effects need to be quantified, and the effects of other confounding variables, such as phase of the nesting cycle, previous experience with aircraft, and sex need to be identified. Overflight variables such as sound level, distance from the nest, and number of exposures need to be related to reproductive success. Because the behavioral response of raptors may influence reproductive success, the probability of an effect after any given response also needs to be determined. Overflight variables should be related to the probability of a raptor response of a given type and intensity. Sources of mortality to eggs, nestlings, fledglings, or adults after disturbances also need to be identified.

OBJECTIVES

The overall goal of this research project was to determine the effects of low-altitude jet aircraft overflights on reproductive success of Peregrine Falcons nesting in east-central Alaska. The following specific objectives were formulated prior to the initiation of the study and largely guided the design and execution of the research project. They are in order of priority, from most to least:

1. Determine the effects of dose (timing, frequency, and intensity) of exposure to jet aircraft overflights on nesting success (proportion of incubating pairs that successfully raise at least one nestling) and productivity (number of nestlings successfully raised per incubating pair).
2. Determine the types and intensities of behavioral responses to jet aircraft overflights by breeding adults and their young.

3. Determine the overflight variables that best correlate with the intensity and type of observed behavioral responses.
4. Determine the influence of phase of the nesting cycle on the type and intensity of behavioral response to jet aircraft overflights.
5. Determine the extent to which the type and intensity of behavioral response to jet aircraft overflights are correlated with subsequent nesting success and productivity.
6. Determine the effects of jet aircraft overflights on time-activity budgets and nestling provisioning rates of adult Peregrine Falcons.
7. Determine the relationship between adult hunting proficiency/prey availability (as indicated by prey provisioning rates) and sensitivity of nesting Peregrine Falcons to disturbance.
8. Determine the extent and time course of habituation (reduction in the intensity of response) to jet aircraft overflights.

STUDY AREA

Our study area in east-central Alaska included Yukon Military Operations Areas (MOAs) 1-5 and the upper Tanana River from Nenana to Tetlin (Figure 1.1). Cliffs along the main rivers in this region (Yukon, Tanana, Porcupine rivers) have a long history of use for nesting by the American subspecies of Peregrine Falcon (*Falco peregrinus anatum*) (Cade 1960, Ambrose et al. 1988). In recent years, use of off-river sites (i.e., sites along tributaries of these main rivers) by nesting Peregrine Falcons has been reported (e.g., Kuropat 1986). Generally, off-river nesting sites are more dispersed and higher in elevation than are nests along the main rivers, and these sites can even be distant from riparian areas altogether.

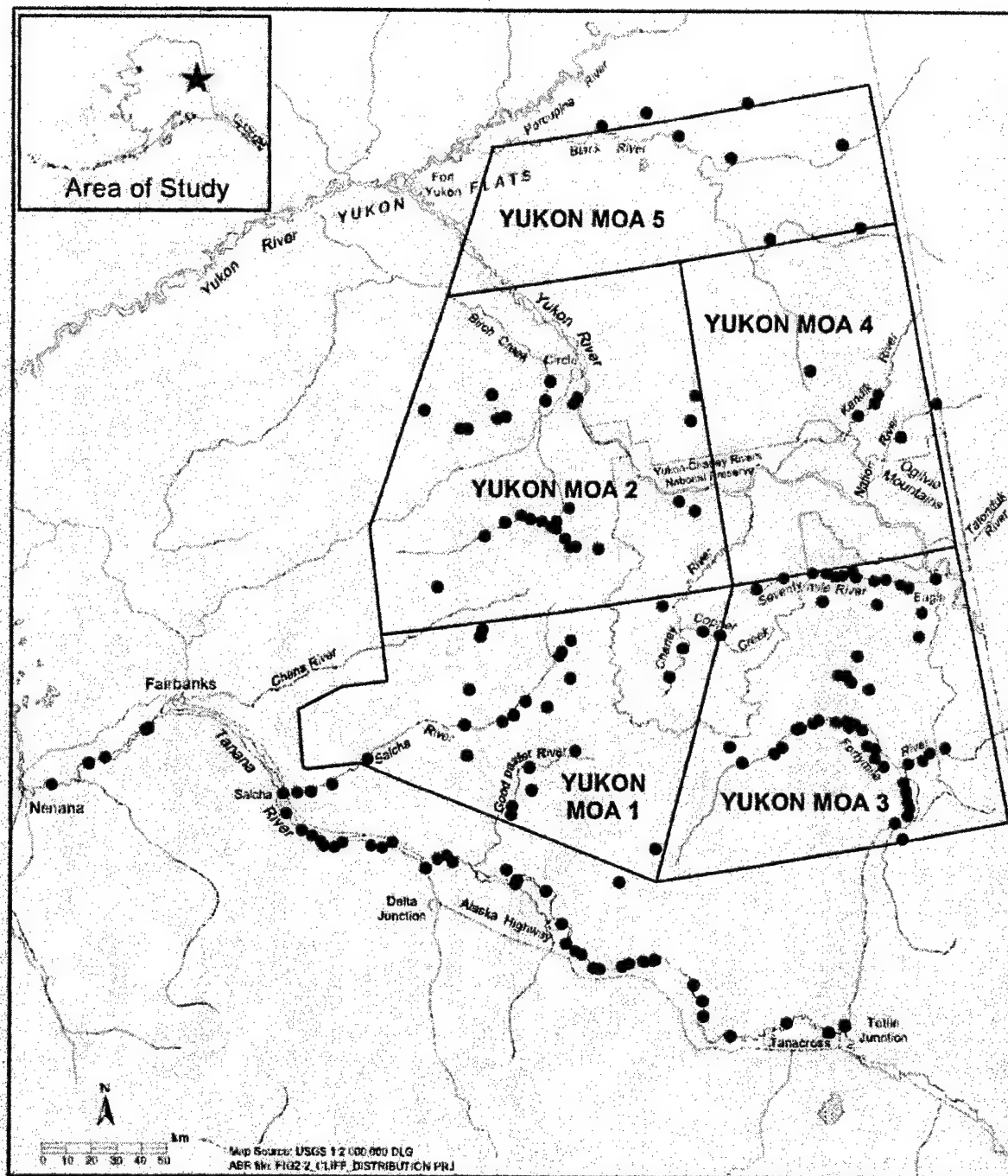


Figure 1.1. *Peregrine Falcon Study Area In East-Central Alaska, 1995–1997 (showing Yukon Military Operation Areas).*

Table 1.1. Number of cliff sites in Yukon MOAs 1 through 5 and along the Upper Tanana River, Alaska, with documented use by Peregrine Falcons, 1994–1998

Region	Drainage	Site occupation		Maximum no. sites used ^a	Total sites ^b
		Pair	Single adult		
MOA 1	Salcha River	13	0	10	13
	Goodpaster River	5	0	5	5
	Healy River	1	1	2	2
	Charley River	3	2	5	5
	Total	22	3	22	25
MOA 2	Birch Creek	21	2	20	23
	Black River	2	0	2	2
	Yukon tributaries	3	1	4	4
	Total	26	3	26	29
MOA 3	Fortymile River	34	2	32	36
	Seventymile River	15	2	13	17
	Total	49	4	45	53
MOA 4	Black River	3	0	3	3
	Kandik River	1	1	2	2
	Nation River	1	2	3	3
	Total	5	3	8	8
MOA 5	Black River	5	1	5	6
	Total	5	1	5	6
Tanana	Tanana River	41	1	40	42
	Tanana River total	41	1	40	42
TOTAL		148	15	146	163

^a = Most sites used in at least 1 year, 1994–1998.

^b = All sites with at least one record of a pair of Peregrine Falcons or a single peregrine.

Our study area is drained by the upper Yukon, Tanana, and Porcupine rivers and their tributaries. The study area is comprised of at least six ecoregions (Gallant et al. 1995), although it is dominated by a mosaic of forests whose occurrence and composition is influenced by factors such as permafrost, wildfire, and aspect. Habitats range from diverse riparian communities along the floodplains, including balsam poplar (*Populus balsamifera*) and white spruce (*Picea glauca*) forests interspersed with willow (*Salix* spp.) and alder (*Alnus crispa*), to mixed dwarf scrub and barren ground above treeline. Black spruce (*P.*

mariana) and broadleaf forest (*Betula papyrifera* and *P. tremuloides*), mixed with graminoid herbaceous meadows dominate the uplands.

Yukon MOAs 1-3 primarily are contained in the Yukon-Tanana Uplands (Wahrhaftig 1965) between the Tanana and Yukon rivers. Other major drainages within these MOAs are Birch Creek and the Salcha, Goodpaster, Healy, Fortymile, Seventymile, and Charley rivers. Rounded, even-topped ridges characterize the area with compact, rugged mountains (1200 - 1500 m [4000 - 5000 ft] in elevation) surmounting this more gentle terrain (Wahrhaftig 1965). Most cliffs are riparian and composed of sedimentary schists, but outcroppings of granite and limestone occur. Off-river rock outcroppings, including granite tors and crests of ridges, are more limited but occur in the upper portions of each drainage. Generally, the area has narrow valleys and few lakes compared to the broad valleys of the Yukon and Tanana rivers.

Yukon MOAs 4 and 5 primarily lie north of the Yukon River. The Ogilvie Mountains, which are drained by the Kandik and Nation rivers, comprise most of MOA 4. These mountains have sharp crestlines (up to 1600 m [5000 ft]) and deep narrow valleys. Primary cliff habitats are riparian and occur where rivers cross cliff-forming layers of rock. Ridges and outcroppings occur on broad piedmont slopes adjacent to these drainages, but many of these cliffs probably are above elevational limits of nesting Peregrine Falcons (i.e., ~1000 m). The Porcupine Plateau between the Yukon and Porcupine rivers comprises most of MOA 5 and is drained entirely by the Black River. Low ridges with gentle slopes and rounded summits (450 - 750 m [1500 - 2500 ft] in elevation) dominate the Porcupine Plateau; cliffs and dirt bluffs generally are limited and along riparian areas. The western portions of MOA 5 (and northwestern corner of MOA 2) overlap the Yukon Flats. The latter area provides little physical relief for cliff nesting raptors, including Peregrine Falcons.

The upper Tanana River between Tanacross and Salcha (63°08'N, 143°36'W to 64°18'N, 148°45'W) comprised the "on-river" portion of our study area. This section of the Tanana River supported more than 30 active Peregrine Falcon nests and was crossed by three Military Training Routes (MTRs; Figure 1.2).

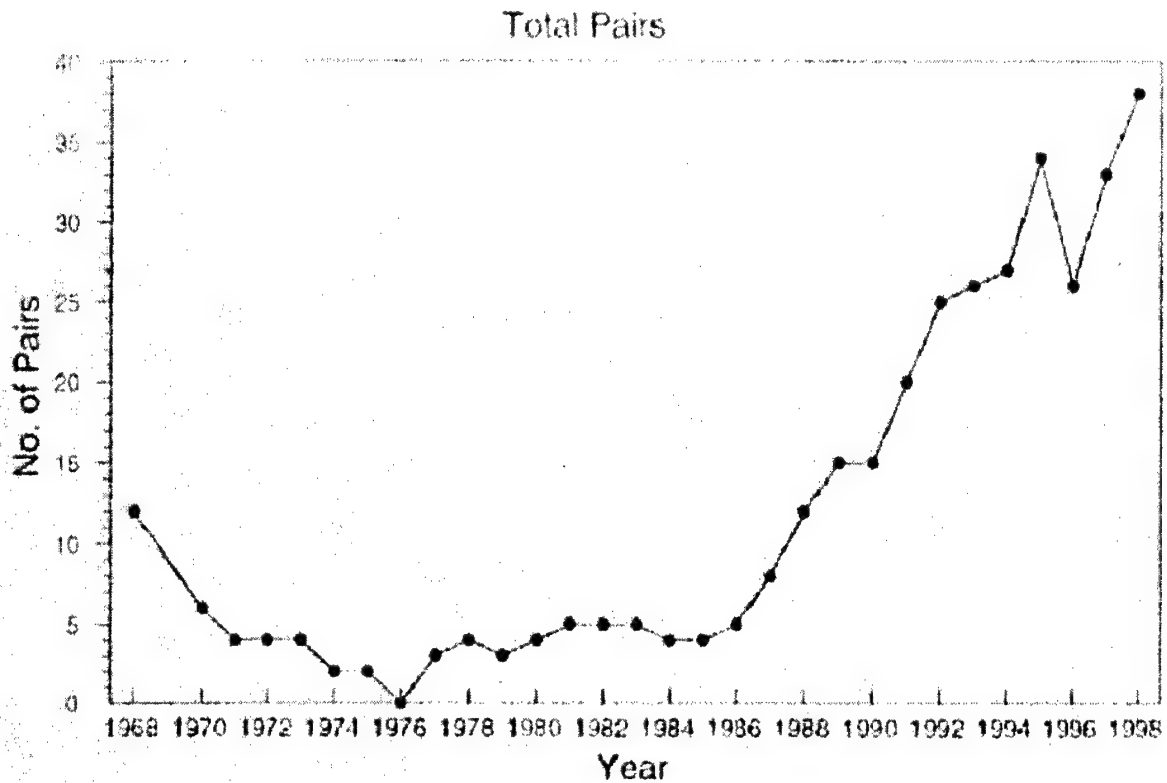


Figure 1.2 Numbers of Peregrine Falcon pairs on the Tanana River, Tok to Nenana, Alaska.

These MTRs are air corridors between Air Force bases and Military Operations Areas (MOAs). All cliffs on the Tanana River are riparian, and nearly all lie north of the river's broad floodplain. These sites are in an area of abrupt transition between upland areas (described above) and the Northway-Tanana and Tanana-Kuskokwim lowlands (Wahrhaftig 1965). The Tanana River is a braided, glacially-fed river. Cliffs of granite and schist rise from 25 - 200 m (80 - 700 ft) above the outwash plain along the river. These slopes and cliffs are where Peregrine Falcons most frequently locate their nests. Some occupied cliffs overlook wide, braided areas of the river, and others are located near lakes, ponds, marshes, or other expanses suitable for hunting. The south-facing slopes where most Peregrine Falcons nest are warmer, sunnier, drier, have a longer growing season, and support a different assortment of plants than do low-lying areas and the backsides of cliffs (Wahrhaftig 1965).

Importantly, this on-river portion of the study area differs substantially from the upland areas in MOAs 1-5, in that it is dominated by a broad valley, numerous large lakes, and a more diverse assemblage of riparian shrub and forested communities. Furthermore, it is a major migration route for many birds that breed in interior and western Alaska (King and Lensink 1971). Consequently, principal avian prey for

Peregrine Falcons, primarily waterbirds, may be more abundant and diverse than in upland and off-river areas.

The entire study area is dominated by a continental climate with short warm summers and long, cold winters (Johnson and Hartman 1969). Certain generalizations can be made regarding important variations in this general pattern, however, that might be important to nesting Peregrine Falcons. First, an orographic effect (related to mountain barriers) on precipitation causes the highlands in the MOAs to receive more precipitation than surrounding lowland areas (Gallant et al. 1995). This might include increased summer rainfall during intense summer storms, which often lead to localized flooding events. Second, summer temperatures typically decrease with increasing elevation, thereby creating a cooler environment in off-river areas.

BACKGROUND

Preliminary observations of the behavioral responses of a pair of breeding Peregrine Falcons to jet aircraft overflights were conducted during the middle of the chick-rearing period in 1994 (Roby et al. 1994). A total of 57 overflight events were recorded during the three days of observation, and 45 of these overflights produced noise levels that exceeded the lower threshold of the noise monitor (75 dB). The responses of the two adult Peregrine Falcons were not pronounced; most overflights were associated with low intensity or non-detectable responses and no flight responses were observed. The adult falcons remained perched near the nest site for most of the three-day observation period, and appeared to gradually habituate to the high frequency of overflights.

Parent Peregrine Falcons may be less willing to leave their brood unattended when there is a perceived threat, and this could negatively affect nestling growth rates and fledging success, especially when prey provisioning rates are suboptimal. We formulated a hypothesis prior to the initiation of this study that the disturbance associated with aircraft overflights results in higher nest attendance and concomitant reductions in foraging time and nestling provisioning rates. Also, during the incubation and nestling brooding phases of the nesting cycle, adult attendance at the nest may be high in response to disturbance, but egg or hatchling neglect may be more frequent as well. These hypotheses provide a potential mechanism for negative effects of overflights on raptor productivity in the absence of overt panic responses by parents and the associated loss of eggs or nestlings. They also provide potential links between prey availability within foraging distance of the nest site and the severity of negative effects from disturbance; parents that are highly proficient at provisioning nestlings may have little difficulty both protecting the brood from perceived threats and providing prey to nestlings at an optimal rate. Lower

quality or inexperienced parents, however, may experience difficulty in optimally allocating time and energy toward self-maintenance, care of progeny, and protection from potential predators.

This hypothesis is supported by the results of a study on the effects of disturbance on reproductive performance in American Kestrels (Carpenter 1993). Significant effects of disturbance on egg production, timing of laying, clutch size, and nesting success were found in one year of a 2-year study, but not in the other. The year when significant effects were observed was a year of relatively low prey availability. The importance of prey availability to disturbance-susceptibility was verified by providing supplemental food to a sub-sample of the disturbed pairs; food supplementation buffered the disturbance effect.

The prey base for Peregrine Falcons in interior Alaska consists almost entirely of birds and the species diversity is high (Hunter et al. 1988). Hunter et al. (1988) found the predominant prey species to be Lesser Yellowlegs; Spotted, Solitary, and Upland Sandpipers; Bohemian Waxwings; Green-winged Teal; Mew and Bonaparte's Gulls; Gray Jays; and Scaup. Most of these species do not experience major population fluctuations in interior Alaska, suggesting that Peregrine Falcon productivity is not strongly prey-limited. Most of the dominant prey species, however, are strongly associated with aquatic habitats, particularly lakes, ponds, and clear streams. The availability of habitat for preferred prey in proximity to the nest site (Hunter et al. 1988), as well as annual and seasonal weather conditions (R. E. Ambrose and P. J. Bente, pers. comm.), may influence prey availability for Peregrine Falcons on spatial and temporal scales. There is considerable inter-annual variation in the average number of young produced per successful pair (1.67-3.26 fledglings per nest; data from the Tanana River, 1980-1994, Bente 1995). Thus certain nest sites in certain years may be more susceptible to disturbance. Alternatively, Peregrine Falcons may rarely be prey-limited during the breeding season because of their catholic feeding habits (R. E. Ambrose and P. J. Bente, pers. comm.), and differences among breeding pairs in hunting proficiency may produce much of the among-nest variation in productivity. This latter hypothesis suggests that breeding pairs that are less proficient at provisioning nestlings are consistently more susceptible to disturbance.

Regardless of whether Peregrine Falcon productivity in interior Alaska is prey-limited, there has been a dramatic increase in the number of active breeding pairs over the last 20 years. On the Tanana River alone, the number of breeding pairs has increased from 0 in 1976 to 27 in 1994 (Bente 1995). Most of this population increase occurred in the late 1980's and early 1990's, so density-dependent population regulation factors may only just now be taking effect. No decline in productivity of breeding pairs is yet evident and population productivity may still be on the increase. But the possibility of density-dependent feedback on productivity must be considered in studies of the effects of disturbance on breeding Peregrine Falcons in interior Alaska.

NATURAL HISTORY OF PEREGRINE FALCONS

Three subspecies of Peregrine Falcons occur in Alaska: Tundra (*F. p. tundrius*), Coastal or Peale's (*F. p. pealei*), and American (*F. p. anatum*). Only the American subspecies breeds in the study area. Prior to population declines induced by pesticides, Peregrine Falcons were the second most commonly observed hawk in Alaska, exceeded in numbers only by whichever species of *Buteo* occurred in the region (Cade 1960). Primarily cliff nesters, the American subspecies of Peregrine Falcon predominantly select ledges or stick nests of other raptors along rivers throughout their range (Cade 1960). Only two reports of tree nests exist for interior Alaska (Cade 1960, White and Roseneau (1970)), although Peregrine Falcons are known to use trees in other subarctic regions (Ratcliffe 1993). Importantly, Peregrine Falcons traditionally return year after year to use the same nesting sites.

Peregrine Falcons in interior Alaska exhibit a fairly consistent range in timing of reproductive events. Arriving at their nesting cliffs by late April or early May, incubation typically is well underway by late May. With an incubation period of 30 days, hatching typically occurs by the second half of June. The nestling period lasts for 35–45 days; thus, fledging usually occurs by early August. Family groups occupy the cliff environment until September or until fall weather stimulates them and their prey to migrate south. Peregrine Falcons are long distance migrants, with subarctic birds moving as far as South America (Yates et al. 1988). Because of the short summer, the potential for renesting after initial failures is limited.

Cliff habitats provide not only a platform for nesting, but also serve as foci for other activities of the breeding pair, including courtship displays, territorial defense, and perching for hunting. Importantly, cliffs usually are associated with water. Not only have watercourses provided the erosional energy for cliff formation, but they also provide a source for bathing, expansive areas for successful hunting, and habitat for many of the waterbirds regularly found in the peregrine's diet (Cade et al. 1968, Ritchie 1976, Hunter et al. 1988).

HISTORICAL STATUS OF PEREGRINE FALCONS IN THE REGION

The entire study area in east-central Alaska is within the historical breeding range of the American subspecies of Peregrine Falcon (Cade 1960). Early naturalist accounts of the avifauna in this region attest to their relative abundance, wide distribution, and to their traditional use of some drainages. For instance, Osgood and Bishop (1900) found peregrines along the upper Yukon River at densities similar to those reported along the same section of river more than half of a century later (Cade 1960, White and Haugh 1969). Other large tributaries in the area have decades old records of nesting or summering Peregrine Falcons: the Fortymile (Grinnel 1909), Tanana (Murie, 1920, unpubl notes, Univ. Alaska Library,

Fairbanks, AK), and Porcupine rivers (Williams 1925). The historical record is not as complete for other drainages in the region, however, and few accounts in this era (e.g., Blackwelder 1919, Osgood 1909) exist for off-river areas in the MOAs.

By the late 1960s and early 1970s, populations of the American and arctic subspecies of Peregrine Falcon declined due to the negative affects of organochlorine pesticide contamination (Cade et al. 1968, Cade et al. 1971). Numbers of breeding pairs were greatly reduced (>50%) on the Yukon and Tanana rivers (Fig 2-2; Cade et al. 1976, Haugh 1976), and estimates for the interior of Alaska suggested that numbers fell to less than a third of the pre-decline numbers (Enderson et al. 1995). The extent of decline on other rivers, including tributaries in the MOAs, was difficult to evaluate because of the lack of pre-pesticide distributional data. Declines may have been even more severe at locations removed from major rivers based on observations for the arctic subspecies, whose numbers declined most severely on tributary drainages (Cade and White 1976).

Recovery and Off-River vs. Main River Areas

Peregrine Falcon populations have been recovering during the past 25 years, and the population that nests along major drainages in interior Alaska now occupies more sites than were historically recorded (Ambrose et al. 1988, Enderson et al. 1995). In addition, numerous sites along small tributaries of these rivers previously undocumented as nest sites have also been occupied (Ritchie 1994). These "off-river" (i.e., off major drainages) populations generally are less dense than populations on the major rivers and have used isolated tors and rock outcrops for nesting (e.g., Kuropat 1986; Ritchie et al. 1998a). Fewer aspects of the life history (e.g., food habits and productivity) of peregrines nesting in off-river sites have been investigated, but these sites probably are less optimal than sites along major rivers.

Since the 1970s, annual monitoring on the major rivers in east-central Alaska has provided a good sequence of recovery of Peregrine Falcons for core areas (Yukon River, Ambrose 1995; Tanana River, Bente and Wright 1995; Porcupine River, Mauer et al. 1991). More extensive raptor surveys on a number of tributary drainages in the Yukon-Tanana Uplands provided baseline information for more remote, less well known areas (e.g., Kandik River, Fadely and Fadely 1993; Charley River, McIntyre 1994). In general, however, surveys on off-river drainages have been more limited and less systematic in most areas where military operations now are occurring (e.g., Black River, Ritchie 1984; Seventymile River, Swem, unpubl. notes), disallowing the formulation of a clear recovery sequence, established for the larger rivers.

In 1993, prior to the initiation of our studies, approximately 130 sites with histories of Peregrine Falcon occupancy were known for the region encompassing the Yukon MOAs 1-5 and the upper Tanana MTRs

(Table 1.1). Roughly half of these sites were found on the main rivers in the region: Tanana, Yukon, and Charley. Additional sites have been identified since 1994, bringing the total to approximately 215 sites known for the region, which is nearly twice the number known in 1993. Some of this increase for the off-river drainages is related to increasing the area of survey coverage (e.g., surveys on the lower Goodpaster), but a substantial portion of the increase is due to the continued recovery of falcons.

Table 1.1. Historical (pre-1994) Peregrine Falcon Sites for Drainages In Yukon MOAs 1-5 and the Tanana River, East-Central Alaska

Drainage	Number of Pairs	Reference
Upper Yukon River	42	Ambrose 1995
Upper Tanana River	26	Bente and Wright 1995
Chena River	1	Roseneau et al. 1981
Salcha River	3	McIntyre et al. 1993; White and Streater 1970
Healy River	0	McIntyre et al. 1993
Charley River	11	C. McIntyre, unpubl. notes
Seventymile River	1	McIntyre 1992
Fortymile River	~25	C. O'Reilly-Doyle, pers. comm.
Black River	3	Ritchie 1984
Kandik River	10	Fadely and Fadely 1993; McIntyre 1992
Nation River	3	Swem 1984; McIntyre 1992
Tatonduk River	2	Swem 1984
Birch Creek	~5	White and Roseneau, 1970; McIntyre et al. 1993; BLM unpubl. maps.
Goodpaster River	0	McIntyre et al. 1993

Endangered Species Status and Subsequent Federal Actions

Concerns about survival of the species led the U.S. Fish and Wildlife Service (USFWS) to list both the American and Arctic subspecies in 1970 as endangered under the Endangered Species Conservation Act of 1969 (Pub.L. 91-135, 83 Stat.275). This classification, modifications (Endangered Species Act 1973; ESA), and subsequent Recovery Plans (USFWS 1982) led to extensive surveys in Alaska to monitor Peregrine Falcon numbers and productivity, including a program to survey every five years as many core population areas as possible (Cade and Fyfe 1970, Fyfe et al. 1976, White et al. 1990). In addition, the

Alaska Native Claims Settlement Act of 1971, a land bill authorizing the Secretary of Interior to withdraw public lands for inclusion within conservation systems, required natural resource inventories (including avifaunal investigations) in the proposed Yukon-Charley National Preserve (Ritchie 1976, Center for Northern Studies 1976).

The ESA also required site and regional environmental assessments where developmental activities might influence the species' abundance (e.g., the Trans-Alaska Pipeline corridor; White et al. 1975).

Consequently, a number of studies to monitor the impacts of aircraft and other disturbances on Peregrine Falcons were sponsored (Windsor 1977, Ritchie 1987, Ellis et al. 1991). In the early 1990s, the U.S. Air Force proposed several changes in their training activities in Alaska, and requested consultation with the USFWS to determine what impacts would likely result from low-level jet overflights (Ambrose 1995). Aircraft Exclusion Zones were established along most major rivers, but cooperative studies were initiated on the Tanana and Yukon rivers, and their tributaries to assess the impacts of jet aircraft on Peregrine Falcons in those areas (Ambrose 1995, this study).

In 1991, the USFWS announced its intent to review the status of both subspecies of endangered Peregrine Falcons (56 FR 26969). With continued recovery of its populations in North America, the American race of Peregrine Falcons now is being considered for delisting (63 FR 45446). Recovery requirements of eventual rulings will mandate monitoring beyond the date of the final rule's acceptance (S. Ambrose, USFWS, pers. comm.). The USFWS and USAF are currently cooperating on a program to continue to monitor Peregrine Falcon productivity and possible impacts of jet aircraft overflights on Peregrine Falcons in east-central Alaska. Many of the MOAs drainages described in this report were surveyed in 1990 (Ritchie, unpubl. draft report to USFWS).

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CHAPTER 2

OCCUPANCY, NESTING SUCCESS, AND PRODUCTIVITY OF PEREGRINE FALCONS IN YUKON MILITARY OPERATIONS AREAS 1 THROUGH 5 AND ALONG THE TANANA RIVER, EAST-CENTRAL ALASKA, 1995 – 1997

Robert J. Ritchie, Stephen M. Murphy & Michael D. Smith

ABSTRACT

We monitored the reproductive effort and performance of nesting Peregrine Falcons in east-central Alaska in portions of U.S. Air Force Yukon Military Operations Areas (MOAs) 1 through 5 (excluding nests along the Yukon River), and along portions of the Tanana River. Helicopter and boat surveys were undertaken during the early- to mid-incubation stages of the nesting cycle to determine nest site occupancy, and sites were revisited during the nestling stage to determine nesting success and productivity. During 1994–1998, Peregrine Falcons were recorded at 163 nest sites; overall, we estimate that ~250 sites have records of use by Peregrine Falcons in Yukon MOAs 1 through 5 and along the Tanana River. Occupancy rates Yukon MOA sites (not including nests along the Yukon River) averaged 68%, whereas rates at sites along the Tanana River (mean = 92%) were significantly higher. Occupancy rates in the Yukon MOAs showed an increasing trend between 1995 and 1997. Nesting success and productivity did not differ between the Yukon MOA sites and the sites along the Tanana River and were similar to other monitoring areas in interior Alaska. Our data suggest that the rate of increase in remote areas off main rivers is substantially higher than current rates of increase recorded for main rivers, where nesting habitats appear to be more saturated and the population is more stable.

INTRODUCTION

The U.S. Air Force's (USAF) Military Operations Areas (MOAs) and Military Training Routes (MTRs) in east-central Alaska encompass many suitable nesting areas for a number of raptors, including the American Peregrine Falcon (*Falco peregrinus anatum*). Because the USAF conducts low-level training exercises in these MTRs and MOAs, the U.S. Fish and Wildlife Service (USFWS) in a letter of Biological Opinion (31 March 1989) determined that the USAF should monitor Peregrine Falcon nesting sites within Yukon MOAs 1 through 5 (but not in the Yukon-Charley Rivers National Preserve) to provide comparisons with protected areas in the Yukon-Charley Rivers National Preserve. In 1993, the USFWS

initiated surveys designed to identify 20 sites in Yukon MOAs 1 and 2 for long-term, annual monitoring (S. Ambrose, USFWS, pers. commun.).

Since 1994, we have conducted a study in portions of Yukon MOAs 1 through 5 and along the Tanana River to monitor the reproductive effort and performance of Peregrine Falcons and to deploy sound-monitoring equipment at a subsample of active nests. Specific objectives of this study were:

1. To identify potential habitat for cliff-nesting raptors, primarily Peregrine Falcons, along the Tanana River and in Yukon MOAs, emphasizing MOAs 1 through 3.
2. To determine the annual occupancy, nesting success, and productivity of a sample of Peregrine Falcon nests found in these regions.
3. To deploy and retrieve compact animal noise monitors (ANMs) for associated disturbance investigations.

During 1995–1997, these surveys were components of the study “Effects of Aircraft Overflights on Birds of Prey,” sponsored by Armstrong Laboratory through the Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska Fairbanks (Ritchie et al. 1998b). In 1994 and 1998, research was supported by USAF (611 ASG/LGV, Elmendorf Air Force Base, Alaska) and coordinated with existing monitoring programs conducted by the USFWS along the Tanana, Yukon, and Charley rivers. This chapter summarizes background information on the occupancy, nest success, and productivity of Peregrine Falcons in Yukon MOAs 1 through 5 and along the Tanana River in Alaska from 1995–1997. Data collected in 1994 and 1998 are incorporated when they improve our assessment of the peregrine population in east-central Alaska.

METHODS

Study Area

The study area in east-central Alaska included Yukon MOAs 1–5 (the MOA portion of the study area) and the upper Tanana River from Nenana to Tetlin (the portion of the study area on a major river; see Figure 2.1). See Chapter 1 of this report for a detailed description of the Yukon MOA and Tanana River portions of the study area.

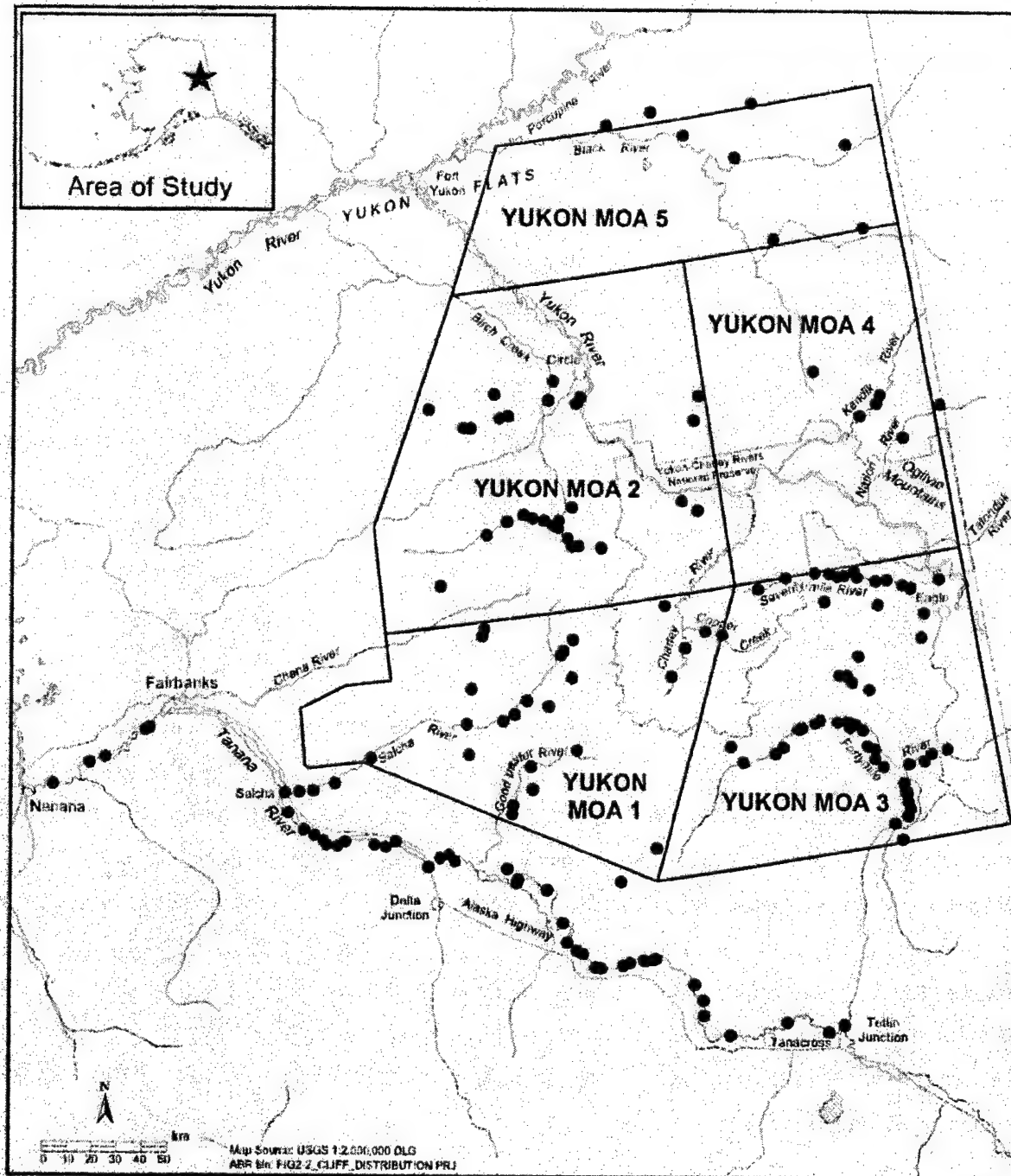


Figure 2.1. *Distribution of cliffs with a history of Peregrine Falcon use in Yukon Military Operations Areas (MOAs) and along the Tanana River, east-central Alaska, 1994–1998*

We used standard sampling techniques for locating raptor nests and for assessing occupancy, nesting success, and productivity (Steenhof and Kochert 1982). When possible, we conducted at least two surveys at each nest site each year. However, a number of elements often associated with aerial survey work in

Alaska (e.g., helicopter logistic constraints such as fuel availability, weather and flight conditions) often limited our ability to visit each nest twice. Consequently, nests with only single surveys are used in this report only for selected analyses where the data are comparable with nests that were visited twice (e.g., analysis of nest occupancy).

Occupancy Assessment

Helicopter and boat surveys were undertaken during early to mid-incubation (from about mid May to early June) to determine nest site or territory occupancy and to deploy noise monitors at active sites. We used helicopters and two observers to visit known and potential Peregrine Falcon nest sites in remote areas of the Yukon MOAs, away from major rivers. Most surveys were conducted in a Hughes 500D helicopter, but a Bell 206 helicopter was employed for some surveys (Appendix 2-A). A Zodiac inflatable raft with outboard motor was used to access all Peregrine Falcon nest sites along the Tanana River in all years except 1997. In 1997, some sites were accessed using a riverboat with a jet outboard motor. Similar surveys were undertaken also in 1998 as part of a USFWS monitoring program supported by the USAF (Ritchie and Rose 1998b). Results from these surveys, as they pertain to occupancy and productivity in monitoring areas, are included in this report.

Standard aerial survey procedures involved flying along the center of a drainage, then angling toward prospective nest sites when the helicopter was approximately 0.8–1.6 km (0.5–1.0 mi) horizontal distance from the cliff, before making a slow (30–60 km/h [20–40 mi/h]) pass by the cliff at a distance of 30–100 m [100–325 ft] from potential nest sites. Multiple passes were made to inspect ledges only where we were convinced that no incubating adults were present or to enable us to closely scrutinize ledges or perches for recent falcon use (i.e., fresh whitewash, scrapes, abandoned eggs). We noted signs of raptor use, including stick nests, ledges, whitewash, and adults. Boat surveys entailed drifting by known and potential nest sites and looking and listening for adult falcons, while also looking for other indicators of raptors (listed above). All our survey protocols conformed with those recommended for surveys as part of a permit to visit endangered Peregrine Falcon nest sites.

At sites where we could not determine status from initial passes (e.g., an adult present, but no incubation activity observed) and at sites with a history of use by peregrines, we landed to better assess the status (e.g., occupied, unoccupied) of the site. We selected landing sites for boats and helicopters based on accessibility for deploying animal noise monitors (ANMs), landing safety, and minimizing disturbance to the birds. Most viewing sites were >200 m (656 ft) from cliffs. While on the ground, we scrutinized available ledges, identified behaviors that would suggest breeding (e.g., aggressive adults, courtship behaviors, incubating adults), and searched for suitable places to deploy ANMs (see Chapter 3 of this

report for deployment details). We used binoculars and a spotting scope to scrutinize ledges that had not been adequately searched from the air. A Questar telescope was used to read color bands at Yukon MOA sites in 1997 and at Tanana River sites in 1996 and 1997. Search time at each nest site ranged from 1–4 hours depending on the cliff size and other factors (e.g., recent history of use).

On all aerial and boat surveys, we recorded all observations of Peregrine Falcons on USGS 1:63,360 topographic maps. During helicopter surveys, we determined precise locations using an onboard Geographic Positioning System (GPS). After all surveys, location data were digitized and incorporated into a Geographic Information System (GIS) database for the region. As required by permit stipulations, each nest site was described on a 'Nest Record' card provided by the USFWS. Information included physical characteristics of the cliff and nest site, location, breeding status, and numbers of peregrines observed.

Productivity Assessment

Sites were revisited during the late nestling stage of the nesting cycle (mid-July), again using helicopters to access Yukon MOA areas and a Zodiac raft to access sites on the Tanana River. A Hughes 500D helicopter with two observers was used most often for aerial surveys, but a Bell 206 aircraft was used for some surveys. On all surveys, we flew by known nest sites to count young and inspect the condition of the site. Following precautions similar to those taken during the first site visit, we often landed near each site for a closer look and to recover the ANM. Some nest sites also were visited to band and measure young and to collect prey remains. Ropes and climbing gear were used to enter more inaccessible nests. Measurements of nestlings included weight, wing chord, tarsal length, length of 7th primary (flight feather), and length of central retrices (tail feathers).

At the time of our second visit, most young were an age suitable for applying leg bands (15–25 days post-hatch), but still partially down-covered and obvious on or near nest ledges. Although at times nestlings were less than the minimum acceptable age for reproduction surveys (~80% age at first flight [Steenhof and Kochert 1982]), most monitoring programs in Alaska use number of young at banding for productivity assessments, because it is impractical to revisit nests again after banding. Thus, we regard our measure of productivity to be a reasonable surrogate for the standard measure and one that allows for comparisons with other monitoring programs in Alaska.

Terminology

Nests located in the Yukon MOAs and monitored as part of this study are referred to as "MOA sites". Most nests in Yukon MOAs 1–5 are not located on major rivers; the exception being nests along the

upper Yukon and lower Charley rivers, which are within the Yukon-Charley Rivers National Preserve and were not monitored in this study. Nests located along the Tanana River that were monitored as part of this study are outside the MOAs and are referred to as "Tanana River sites".

The terms "site" and "nest site" are used interchangeably in this report and represent locations with evidence of breeding by Peregrine Falcons. In addition to confirmed nest locations, sites also included cliffs where peregrine adults (singles and pairs) were recorded and showed an affinity to the site (i.e., remained on or in the vicinity of the cliff during surveys) and use by peregrines was apparent (e.g., prey remains characteristic of peregrines, used ledges).

Steenhof (1987) recommends not using the term "active" because of inherent ambiguities. Postupalsky (1974), however, used the term active to describe the presence of pairs in a territory. On our surveys and in previous reports, we used the term "active site" to denote a site where either adults were seen incubating or young were observed. This determination was particularly important during placement of ANMs. In our data summaries herein, we use "occupied site" to denote the presence of a pair or at least one adult bird showing a clear territorial affinity to a cliff (e.g., aggressive behavior). Total sites are all occupied sites, unless otherwise noted. We use the term "successful site" to describe sites that produced at least one young. However, we estimated productivity only for nests with young developed to banding age (~15–25 days old) and only if all nestlings could be counted.

Data Analysis

Reconnaissance surveys conducted in 1994 (Ritchie and Rose 1994) helped to delineate major areas that would be monitored for aircraft disturbance in each of the following three years. For data summary and analysis purposes, survey areas are classified as "Monitoring" or "Irregular" areas. Monitoring areas occurred along drainages within MOAs 1–3 where complete censuses of all cliffs were undertaken in 1995–1997. These areas included all or portions of upper Birch Creek, Salcha, Goodpaster, and Seventymile rivers, and the North and Middle forks of the Fortymile River. Data from these sites provide the basis for determining annual occupancy, nesting success, and productivity in different subregions of the study area. These data also are critical in evaluating the recovery status of the population and its relationship to other populations.

Irregular areas included drainages that were censused, but where logistic constraints on helicopter surveys did not allow the same regional thoroughness and/or surveys were conducted in only one or two years. Irregular areas included lower portions of Birch Creek (Crazy Hills) and the Fortymile River, and the Nation, Kandik, Black, Healy, and Chena rivers. Records from these surveys primarily are used to

improve our understanding of the distribution and abundance of peregrines in the region. However, if sites in the irregular areas were visited twice in the same year, the data are included in summaries of productivity and nest success for given years.

Our surveys on the Tanana River for the USAF disturbance study did not extend beyond the experimental and reference study sites (between Tanacross and Salcha). However, more complete census information was gathered during other investigations and these results are incorporated in this report. In 1995, for example, the Alaska Department of Fish and Game (ADFG) conducted occupancy and productivity surveys on the Tanana River from Tetlin Bridge to Nenana (Bente and Wright 1995; P. Bente, ADFG, pers. comm.), and in 1997 and 1998, similar surveys were conducted from Tetlin Bridge to Fairbanks and Nenana, respectively, as part of a USFWS/USAF-supported monitoring study (Ritchie and Rose 1997; Ritchie and Rose 1998a, 1998b). Surveys on the Tanana River in 1996 occurred between Tok and Fairbanks and, although some cliffs were not visited twice, selected data are used in this report.

For productivity analyses, total young equaled the minimum number of young counted at sites where brood counts were made. Subsequent calculations of young/pair for productivity comparisons only included pairs where two surveys were conducted and the entire brood was counted. Occupancy of all sites in each drainage was calculated by taking the number of monitoring sites with at least one adult present in a given year and dividing that number by the greatest number of sites identified in that drainage during all survey years.

Analysis of variance (ANOVA) was used to test whether nest occupancy rates differed among the five MOAs and Tanana River nests, or among any of the various drainages. ANOVA also was used to assess productivity (number of young per total pair and number of young per successful pair) among the MOAs and drainages. We report *P* values for all statistical tests. Tests with $P < 0.05$ are considered significant, tests with $0.05 < P < 0.10$ are considered marginally significant, and tests with $P > 0.10$ are considered not significant.

RESULTS

Spring and Summer Weather Conditions

Weather conditions during the nesting period can affect Peregrine Falcons by reducing nest-site availability and increasing nestling mortality (Newton 1979). Based on temperature and precipitation data from Fairbanks and Eagle, weather conditions in the study area during the breeding season (May–July, 1995–1998) generally were similar to or slightly above long-term averages (Table 2.1). The warmest years were 1995 and 1997, when temperatures were above average during the breeding season. May 1995

was somewhat anomalous, however, because record high temperatures in the first half of the month were followed by unseasonably cold temperatures in the second half of the month (Figure 2.2). The latter period included a wet snow above ~600 m (1968 ft) elevation that came at a time when peregrines were beginning incubation. Temperatures in the study area in 1996 and 1998 also generally were near or above normal during the breeding season (May–July).

Table 2.1. *Deviations from monthly average temperatures (°F) and precipitation during May–July at Eagle and Fairbanks, Alaska, 1995–1998 (from unpublished weather records, U.S. Department of Commerce)*

Year	Location	May		June		July	
		Temp.	Precip.	Temp.	Precip.	Temp.	Precip.
1995	Fairbanks	+4.9	+0.12	+1.1	+0.54	+0.6	-0.55
	Eagle	+5.3	+0.21	+2.8	+0.84	+0.2	+1.28
1996	Fairbanks	+0.5	-0.47	-0.3	+0.19	+1.0	-0.80
	Eagle	+0.1	-0.30	-0.2	-0.45	+1.4	-0.81
1997	Fairbanks	+0.4	-0.54	+3.3	-0.34	+2.4	-0.79
	Eagle	+1.1	+0.70	+0.4	+1.24	+2.2	+0.92
1998	Fairbanks	+1.4	-0.20	-1.0	-0.04	+0.2	+1.48
	Eagle	+5.2	+1.43	+0.4	+1.44	+2.7	-0.59

Overall, precipitation in 1995 was normal, whereas 1996, 1997, and 1998 were drier than normal in Fairbanks. Precipitation was above average in Eagle for most of the summer in 1997 and in 1998. Only trace amounts of precipitation were recorded in May 1995, and precipitation levels were 0.54–0.79 inches less than normal from May through July 1997 near Fairbanks (Table 2.1). In addition, low water levels in upper tributaries throughout summer in 1996 and 1997 suggested infrequent summer storm events. In 1995, although precipitation measures were average and there were no extended dry periods, localized storms and high water occurred in the region at least during June. Partial flooding occurred in the upper Chena River in late June.

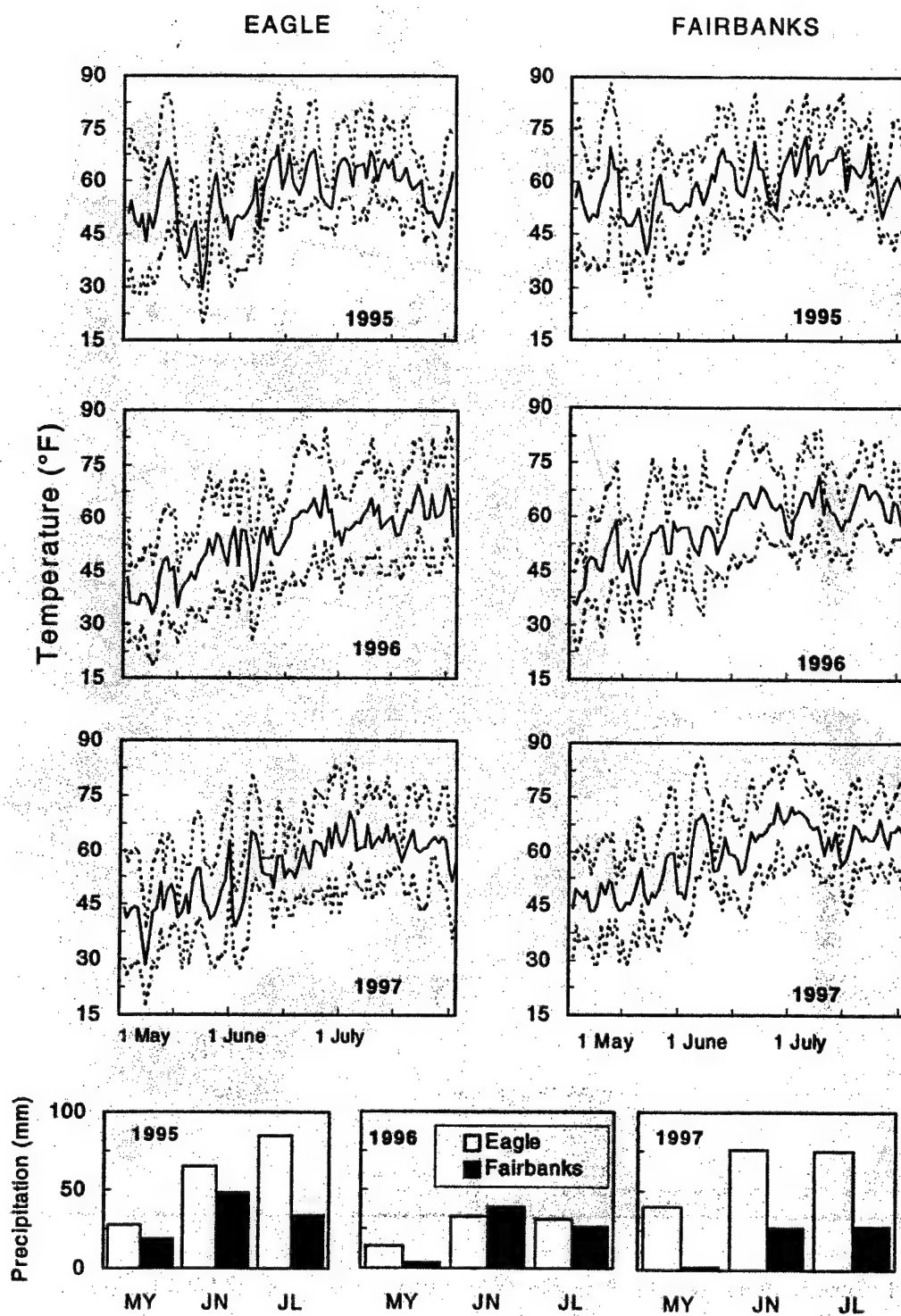


Figure 2.2 Daily maximum, minimum, and average temperatures and monthly precipitation during May, June, and July, 1995-1997, in Eagle and Fairbanks, Alaska

Peregrine Falcon Distribution and Abundance

During aerial surveys between 1994 and 1998, Peregrine Falcons (singles and pairs) were recorded at 163 cliff sites within MOAs 1 through 5 and along the Tanana River (Table 2.2 and Figure 2.1). Pairs occupied 148 of these cliffs (91%) in at least 1 year during our investigations. The remaining 15 sites also probably were used for nesting, but only single birds were recorded during all years of surveys. Nearly 75% of all cliff sites used by peregrines were located in MOAs 1 through 5; the remaining sites (42) were regularly used sites along the Tanana River between Tetlin Junction and Nenana.

Table 2.2. *Number of cliff sites in Yukon MOAs 1 through 5 and along the Upper Tanana River, Alaska, with documented use by Peregrine Falcons, 1994–1998*

Region	Drainage	Site occupation		Maximum no. sites used ^a	Total sites ^b
		Pair	Single adult		
MOA 1	Salcha River	13	0	10	13
	Goodpaster River	5	0	5	5
	Healy River	1	1	2	2
	Charley River	3	2	5	5
	Total	22	3	22	25
MOA 2	Birch Creek	21	2	20	23
	Black River	2	0	2	2
	Yukon tributaries	3	1	4	4
	Total	26	3	26	29
MOA 3	Fortymile River	34	2	32	36
	Seventymile River	15	2	13	17
	Total	49	4	45	53
MOA 4	Black River	3	0	3	3
	Kandik River	1	1	2	2
	Nation River	1	2	3	3
	Total	5	3	8	8
MOA 5	Black River	5	1	5	6
	Total	5	1	5	6
Tanana	Tanana River	41	1	40	42
	Tanana River total	41	1	40	42
TOTAL		148	15	146	163

^a = Most sites used in at least 1 year, 1994–1998.

^b = All sites with at least one record of a pair of Peregrine Falcons or a single peregrine.

Most MOA sites were found on primary tributaries of the Yukon and Tanana rivers; specifically the Birch Creek and the Fortymile, Seventymile, Salcha, Black, Goodpaster, and Charley rivers (Table 2.2, Figure 2.1). Only 9 sites were found on the Nation and Kandik rivers, and on small creeks draining north into the Yukon River between Circle and the mouth of the Charley River (hereafter referred to as "Yukon tributaries"), but survey coverage was limited in these regions. No nests were located on the main, south, and middle forks of the Chena River.

MOA nest sites occurred on a wide variety of cliffs, but generally were near (<100 m [328 ft]) or fronted riparian habitats. Exceptions included a few tors and upland sites, distant (>500 m [1640 ft]) from well-developed riparian areas in the Crazy Hills of Birch Creek (5 sites), upper Seventymile tributaries (2), Salcha (1), Fortymile (1), and Goodpaster (3) rivers. Cliffs ranged from 20 to >250 m (66 to >820 ft) in height, with the tallest cliffs along the Tanana River and along the Fortymile and Seventymile rivers and upper Birch Creek. Nearly all nest sites occurred on rock ledges on cliffs or on talus slopes. Peregrine nests also were found on soil banks (2 sites) and in stick nests (9 sites) during 4 years of surveys. The majority of cliffs (>90%) in the MOAs, including those along the Salcha, Goodpaster, Seventymile, and Fortymile rivers and Birch Creek were between 457 and 762 m (1499 and 2500 ft) above sea level (ASL); range = 230–1037 ASL. Over 80% of all cliffs were between 305 and 610 m (1001 and 2000 ft) along the Tanana River (range = 152–686 m [499–2251 ft]). Information on the location and status of all sites, as well as additional sites adjacent to the MOAs, are summarized in Appendix 2-B.

Occupancy

A subsample of the peregrine nests in our study area were monitored consistently each year. In the MOAs, 66 sites were monitored on 5 tributaries (Table 2.3). Coverage on the Tanana River varied among years, with the number of nest sites checked ranging from 33 to 42. Within the MOAs, 92% of the sites were occupied at least once during the period from 1995–1997; percentages of sites used in 1, 2, and 3 years were 21, 34, and 44%, respectively.

Table 2.3. *Numbers of historic sites checked, and occupancy of those sites by Peregrine Falcons in monitoring areas, east-central Alaska, 1995–1998*

Region or tributary	Year	Number of sites			% occupied ^b
		Checked	Pairs	Total ^a	
All MOA sites	1995	66	29	37	56
	1996	66	41	48	73
	1997	66	47	50	76
	1995–1997	198	117	135	68
Goodpaster River (MOA 1)	1995	5	1	1	20
	1996	5	4	4	80
	1997	5	4	4	80
	1998	5	5	5	100
	1995–1998	20	14	14	70
Salcha River (MOA 1)	1995	11	4	7	64
	1996	11	5	6	55
	1997	11	6	7	64
	1998	11	8	10	91
	1995–1998	44	23	30	68
Birch Creek (MOA 2)	1995	17	7	9	53
	1996	17	11	14	82
	1997	17	11	14	82
	1998	17	12	12	71
	1995–1998	68	41	49	72
Fortymile River (MOA 3)	1995	18	7	9	50
	1996	18	11	12	67
	1997	18	14	14	78
	1995–1997	54	32	35	65
Seventymile River (MOA 3)	1995	15	10	11	73
	1996	15	10	12	80
	1997	15	9	11	73
	1995–1997	45	29	34	76
Tanana River	1995	36	32	34	94
	1996	33	24	29	88
	1997	41	33	36	88
	1998	42	37	40	95
	1995–1998	153	127	140	92

^aTotal sites include sites with at least one adult Peregrine Falcon.

^b% occupied = total sites/checked sites

Occupancy of MOA sites by peregrines averaged 68% (range 56–76%) for all survey years (Table 2.3). Occupancy on the Tanana River was significantly higher (ANOVA; $F = 10.97$; $P = 0.30$) than in the MOAs and averaged 92% between 1995 and 1998. The lowest occupancy rate was recorded on the Goodpaster River in 1995 (20%), and the highest occupancy rate was recorded for the Tanana River (95%) in 1995.

Nesting Success and Productivity

Nesting success and productivity were evaluated each year for all active nests in the study area with known fate; hence, sample sizes differ somewhat from those presented for occupancy analyses. Nesting success, or the percentage of pairs producing at least one young, averaged 73% for all MOAs combined during 1995–1997, and ranged between 67 and 75% (Table 2.4). Individual MOAs varied more, from a low of 40% nesting success in MOA 1 in 1995 to a high of 89% in MOA 3 in 1996. Average annual nesting success was slightly higher at the Tanana River sites (77%; range = 71 to 85%) than at MOA sites, but this difference was not significant (Table 2.3).

Table 2.4. *Nesting success and productivity^a of Peregrine Falcons at nest sites in Yukon MOAs 1 through 4 and along the Tanana River between Tetlin Junction and Nenana, Alaska, 1995-1997*

Region or tributary	Year	Total pairs	Succ. pairs	No. of nests by brood size				Total young	Mean brood size		% successful
				1	2	3	4		Young/succ. pair	Young/total pair	
All MOAs	1995	27	18	0	7	9	2	49	2.7	1.8	67
	1996	44	33	3	17	7	6	82	2.5	1.9	75
	1997	52	39	7	19	13	0	84	2.2	1.6	75
	Total	123	90	10	43	29	8	215	2.4	1.8	73
MOA 1	1995	5	2	0	1	0	1	6	3.0	1.2	40
	1996	10	7	1	1	2	3	21	3.0	2.1	70
	1997	10	8	1	3	4	0	19	2.4	1.9	80
	Total	25	17	2	5	6	4	46	2.7	1.8	68
MOA 2	1995	7	6	0	2	3	1	17	2.8	2.4	86
	1996	16	10	1	4	3	2	26	2.6	1.6	63
	1997	15	13	1	7	5	0	30	2.3	2.0	87
	Total	38	29	2	13	11	3	73	2.5	1.9	76
MOA 3	1995	13	8	0	3	5	0	21	2.6	1.6	62
	1996	18	16	1	12	2	1	35	2.2	1.9	89
	1997	27	18	5	9	4	0	35	1.9	1.3	67
	Total	58	42	6	24	11	1	91	2.2	1.6	72
MOA 4	1995	2	2	0	1	1	0	5	2.5	2.5	100
Tanana River	1995	31	23	0	7	11	5	67	2.9	2.2	74
	1996	24	17	2	6	6	3	44	2.6	1.8	71
	1997	33	28	4	10	10	4	70	2.5	2.1	85
	Total	88	68	6	23	27	12	181	2.7	2.1	77

^aNest fate is known and determined by two surveys. No incomplete brood counts have been included

Mean brood size at MOA sites between 1995–1997 was 2.4 young/successful pair (range = 2.2–2.7) and 1.8 young/total pair (range = 1.6–1.9; Table 2.3). Overall, productivity was lowest in MOA 3 (Seventymile and Fortymile rivers) for all years combined (2.2 and 1.6 young/successful pair and young/total pair, respectively). Mean productivity for Tanana River sites was slightly higher (2.7 young per successful pair and 2.1 young per total pair) than that recorded for MOA sites, but these differences were not significant (young per successful pair—ANOVA, $F = 1.125$, $P = 0.349$; young per total pair—ANOVA, $F = 3.2$, $P = 0.148$).

Peregrine Numbers in Monitoring Areas

Numbers of Peregrine Falcon pairs and sites occupied by at least a single bird increased along all tributaries in MOAs 1 through 3 between 1995 and 1997 (Figure 2.3). For all of the monitoring areas in MOAs 1 through 3 combined, numbers of pairs increased more between 1995 and 1996 (41%), than they did from 1996 to 1997 (10%; Table 2.5). Except for the Tanana River and Birch Creek (MOA 2), increases in total pairs generally were greater between 1995 and 1996 compared to 1996 and 1997 for all tributaries. Peregrine numbers apparently declined on the Tanana River from 1995 to 1996 (-3 and -14% for total sites and pairs, respectively) but increased in 1997 to numbers similar to those recorded in 1995. (Unfortunately, the degree of decline may be due partially to survey inadequacy in 1996, as some sites were not checked as thoroughly as in 1995 or 1997.) Numbers of peregrines increased on Birch Creek in 1996, but not in 1997.

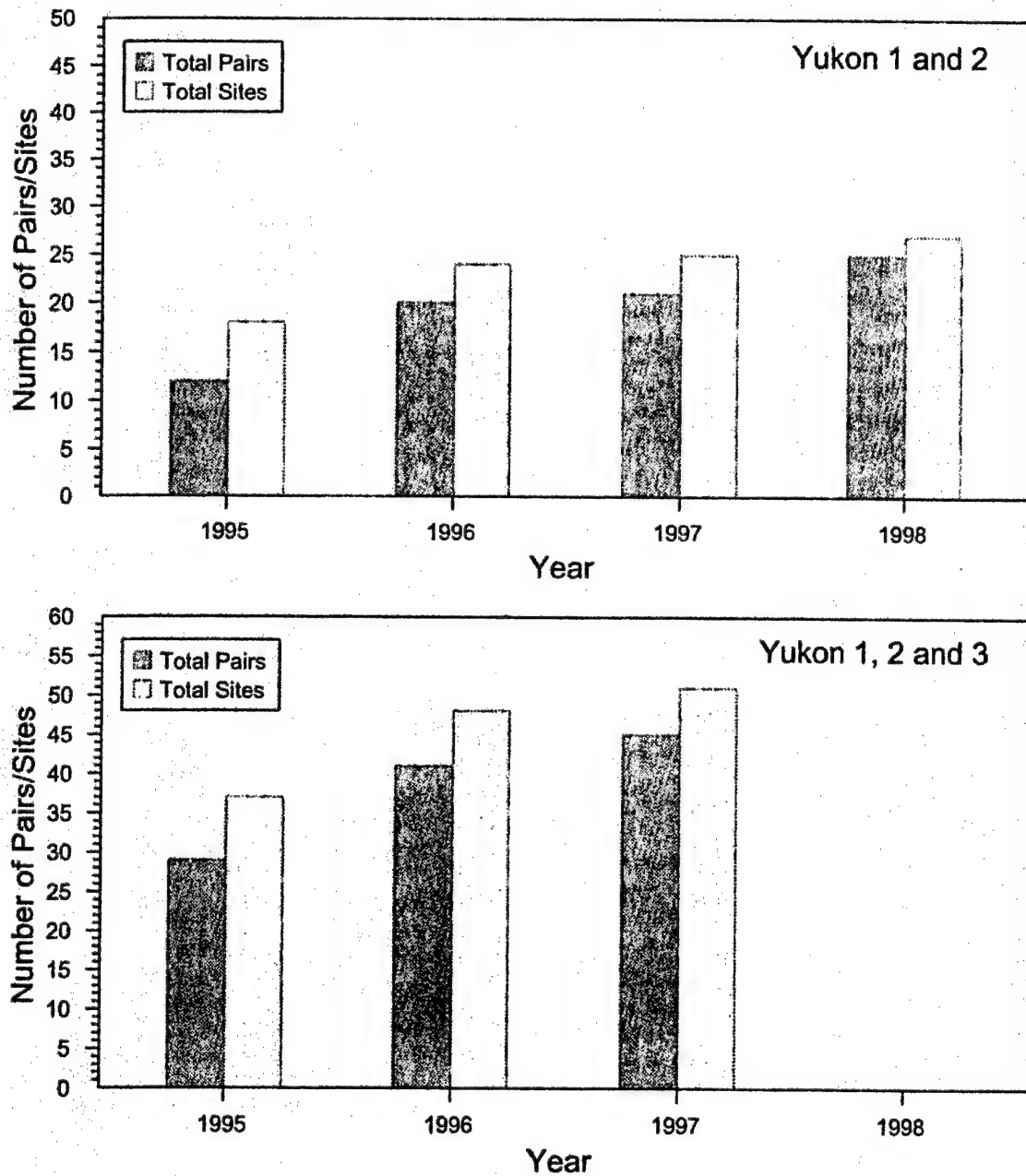


Figure 2.3. Numbers of pairs and occupied sites (pairs or single adults) of Peregrine Falcons in monitoring areas of Yukon Military Operations Areas (MOAs) 1 and 2 (1995–1998) and MOAs 1 through 3 (1995–1997), east-central Alaska

Table 2.5. Numbers of Peregrine Falcons and rates of change for monitoring areas in MOAs 1 through 3 and the Tanana River, Tetlin Bridge to Fairbanks, Alaska, 1995–1998

Region or tributary	Year	Number of sites			Change (%)	Total sites ^a	Change (%)
		Checked	Singles	Pairs			
MOA 1	1995	16	3	5		8	
	1996	16	1	9	80	10	25
	1997	16	1	10	11	11	10
	1998	16	2	13	30	15	36
MOA 2	1995	17	2	7		9	
	1996	17	3	11	57	14	56
	1997	17	3	11	0	14	0
	1998	17	0	12	9	12	-14
MOA 3	1995	33	3	17		20	
	1996	33	3	21	24	24	20
	1997	33	2	24	14	26	8
MOAs 1 and 2	1995	33	5	12		17	
	1996	33	4	20	67	24	41
	1997	33	4	21	5	25	4
	1998	33	2	25	19	27	8
MOAs 1, 2 and 3	1995	66	8	29		37	
	1996	66	7	41	41	48	30
	1997	66	6	45	10	51	6
Tanana River ^b	1995	34	2	28		30	
	1996	34	5	24	-14	29	-3
	1997	34	2	27	13	29	0
	1998	34	1	31	15	32	10

^aTotal sites equal all sites with at least 1 Peregrine Falcon pair or a single adult.

^bTanana River does not include MOA sites or sites below Salcha.

Increases were apparent again in 1998 for monitoring areas MOA 1 (Goodpaster and Salcha rivers) and along the Tanana River, but in the Birch Creek monitoring areas in MOA 2 overall use (total sites) declined by 14% from the previous year. Numbers of pairs along Birch Creek increased by one pair from counts in 1997, however. Numbers of Peregrine Falcon pairs in all the MOA monitoring areas and on the Tanana River were highest in 1998 compared to previous survey years. The rate of increase from 1997 to 1998 varied among survey areas, and was less than the increase calculated for 1995–1996

DISCUSSION

Distribution and Abundance

Peregrine Falcons in east-central Alaska typically use cliffs in riparian habitats for nesting. Exceptions include a few more remote tors and upland sites, but these sites generally are within 2 km of riparian areas. The highest suitable cliffs and isolated outcrops >1000 m (3281 ft), however, generally were not occupied by peregrines during our surveys. Instead, most alpine cliffs at these elevations had signs of use by Gyrfalcons (*Falco rusticolus*), including substantial guano deposits and pothole ledges used for nesting by this species. Some of these sites may be used by both species, and we will be interested to see if peregrines attempt to use some of these higher cliffs if their numbers continue to increase. McIntyre (1992) located an active peregrine nest in an alpine area over 1000 m (3281 ft) in the Ogilvie Mountains near Eagle, Alaska, and we reported one failed nest at ~ 1100 m (3609 ft) in the upper Salcha River region. Cade (1960) suggested a general elevational limit of ~ 610 m (2001 ft), but earlier accounts of peregrines at higher elevations in the region's upland areas (e.g., Blackwelder 1919) lend historical credence to higher nest locations.

Interestingly, no peregrines were found on the upper Chena River, although cliffs similar to those along other tributaries with peregrines (e.g., Birch Creek, Salcha River) occur on the middle and south forks of the Chena. A single nest site, just outside the western boundary of MOA 1, has been identified along the lower Chena River (White and Streater 1970); the nest site recently has been occupied. The river valley is well developed in its lower reaches, but so are peregrine-occupied portions of the lower Salcha and Tanana rivers where peregrines regularly nest.

Combining our findings with the results of surveys in separate and distinct geographical areas in the region provides a conservative means to estimate total numbers of nesting Peregrine Falcons in east-central Alaska. Currently, we estimate that 250 sites have records of use by peregrines in MOAs 1 through 5 and along the Tanana River (Table 2.6). This number probably represents 200+ pairs using the

region annually. Earlier estimates of 150 to 300 pairs for the entire forested interior of Alaska (Cade 1960, Ambrose et al. 1988) are undoubtedly low and outdated.

Table 2.6. *Historical records and current minimum estimates of Peregrine Falcon nest sites for drainages in MOAs 1 through 5 and on the Tanana River, east-central Alaska.^a*

Drainage	Number of sites			Sources
	This study ^b	Other studies	Estimated total	
Upper Yukon River	—	47	47	R. Ambrose (U.S. Fish and Wildl. Serv., unpublished data 1997)
Upper Tanana River	40	2	42	Bente and Wright (1995)
Chena River ^c	0	1	1	Roseneau et al. (1981)
Salcha River	10	4	14	McIntyre et al. (1993); White and Streater (1970)
Goodpaster River	5	1	6	McIntyre et al. (1993)
Healy River	2	0	2	McIntyre et al. (1993)
Charley River	5	(17)	22	McIntyre (1996)
Birch Creek	20	(1)	21	White and Roseneau (1970); McIntyre et al. (1993); Bur. Land Manage. (BLM), unpublished maps
Seventymile River	13	0	13	McIntyre (1992)
Fortymile River	32	(10)	42	C. O'Reilly-Doyle (BLM, pers. commun.)
Black River	10	(2)	12	Ritchie (1984)
Kandik River	2	8	10	Fadely and Fadely (1993); McIntyre (1992)
Nation River	3	(2)	5	Swem (1984); McIntyre (1992)
Tatonduk River	—	(2)	2	Swem (1984); McIntyre (1992)
Other Yukon tributaries ^d	4	(5)	9	McIntyre (1992)

^a0 = no nests; — = no survey; (#) = estimate of additional unique sites.

^bChena River site is outside of Yukon MOA 1.

^cOther Yukon = small drainages entering Yukon River between Circle and Eagle (e.g., Coal Creek).

^dMaximum number of sites occupied in at least 1 year during 1995–1998.

Occupancy

Peregrines in stable populations typically occupy 80–90% of all territories in any year (Ratcliffe 1993, Enderson et al. 1995). Occupancy rates dropped to 65% in the arctic region and 55% in the subarctic region of Alaska during the declines of the 1970s (Ambrose et al. 1988). Occupancy rates elsewhere may reflect more dynamic situations. In the Keewatin district of Northwest Territories (NWT), occupancy

averaged 73% for the period 1983–1985 (Bromley 1988), but less than 50% along the MacKenzie River Valley during the same period (Bromley and Matthews 1988). Because numbers of peregrines are thought to have increased beyond historical levels in some areas, calculating rates of occupancy becomes complicated as additional sites are identified.

Occupancy rates in our study area were high and showed a general increasing trend between 1995 and 1997, particularly at MOA sites. Increases in occupancy continued into 1998 for sites surveyed in that year. Occupancy rates on the Tanana River were higher and more consistent than in the MOAs from 1995–1998, and are probably indicative of a more stable or more slowly growing population on the Tanana River. More years of surveys are needed to determine whether the increasing occupancy rates that we observed reflect long-term recovery or shorter term population fluctuations.

Some of the differences in occupancy rates between the MOA sites and sites along the Tanana River might be due to greater survey efficiency on the Tanana, which was surveyed by boat, than in the MOAs, which were surveyed by aircraft. Lower occupancy rates at MOA sites also may reflect poorer habitat quality in these areas and greater dependency on alternative, often marginal, nest sites. Most species of raptors have several alternate nest sites in a territory (Newton 1979), but for peregrines' high quality habitat, these alternates may be simply other ledges or potholes on the same cliff face or on another cliff nearby. With an increasing use of smaller, marginal cliffs, alternates may occur at greater distance from each other. Court et al. (1988) discovered that many "new" pairs established themselves between historic sites, but frequently failed to return to the cliff the next year. This new site became an historic site, but the pair may have moved on to another new site the following year. During a 9-year study in Scotland, researchers also found that as the population rose, more peregrines were forced to use small cliffs (Mearns and Newton 1988). Because nesting success was related to the size of cliffs and their accessibility, smaller sites were abandoned or disused more frequently. The short-term nature of our monitoring disallows a more detailed discussion on the relationships of performance and habitat on occupancy.

Nesting Success and Productivity

Nesting success and productivity of Peregrine Falcons during 1995–1997 was not significantly different between the nests in the MOAs and nests along the Tanana River. Furthermore, overall nesting success in our study area was comparable to other monitoring rivers in the region (Porcupine, Charley, and Yukon rivers) during the same period (Table 2.7). Nesting success has varied among studies elsewhere in the peregrine's range. For example, nesting success ranged from 50–100% for pairs on the MacKenzie River,

NWT, 1980–1985 (Bromley and Matthews 1988). Mearns and Newton (1988) reported an average nesting success of 60% for a pooled sample of peregrine nests in southern Scotland, 1974–1982.

Productivity in our study area also was similar to that reported for other areas monitored in east-central Alaska during 1995–1997 (Table 2.7; unpublished summaries, USFWS, Fairbanks, Alaska). In addition, brood sizes were similar to mean brood sizes calculated for *anatum* populations at other locations during the last 2 decades (MacKenzie Valley, NWT, Bromley and Matthews 1988; Porcupine River, Alaska, Ritchie 1984, Mauer et al. 1991; lower Yukon River, Bente et al. 1983). On the Yukon River during 1977–1997, for example, mean brood size averaged 1.8 young/total pair; mean brood size in the MOAs and the Tanana River was 1.8 and 2.1 young/total pair, respectively, from 1995–1997. This range of values simply may reflect natural annual variation in nesting success and productivity, or it could be the result of different habitat conditions, different population composition, and/or disturbance (see Chapter 10 of this report).

Table 2.7. *Comparisons of nesting success and productivity of Peregrine Falcons in MOAs 1 through 4 and major rivers in east-central Alaska, 1995–1997^a*

Year	Region	Lone adults	Total pairs	Successful pairs	Young/succ. pair	Young/total pair	% pairs successful
1995	Charley River	1	13	9	2.7	1.9	69
	Porcupine River	4	30	24	2.3	1.8	80
	Tanana River	2	31	23	2.9	2.2	74
	Yukon River	3	43	30	2.4	1.7	70
	All MOAs	10	27	18	2.7	1.8	67
1996	Charley River	1	16	14	2.3	2.0	88
	Porcupine River	1	30	19	2.3	1.4	63
	Tanana River	5	24	17	2.6	1.8	71
	Yukon River	4	41	26	2.5	1.6	63
	All MOAs	9	44	33	2.5	1.9	75
1997	Charley River	na	na	na	na	na	na
	Porcupine River	6	26	22	2.3	1.9	85
	Tanana River	3	33	28	2.5	2.1	85
	Yukon River	3	44	27	2.2	1.4	61
	All MOAs	8	52	39	2.2	1.6	75

^aSources: Charley River (McIntyre 1996); Porcupine River and Yukon River (unpublished summary tables, US. Fish and Wildl. Serv., Fairbanks, Alaska); Tanana (this study); MOAs (this study). na = not available.

Values of young per total pair were low for some remote areas like the Salcha River, and nesting success in 1995 for all MOAs was the lowest recorded during the 3 years of study. In addition, numbers of single adults recorded in 1995 were the highest recorded among years, possibly related to an early reduction in nesting efforts. Weather may have been an influence. The spring of 1995 may have been the least favorable for nest initiation in all years of the study. After higher than normal temperatures at the onset of May, freezing temperatures, snow, and heavy precipitation occurred at a time when peregrines were involved in pre-laying and laying activities (late May). Furthermore, poor weather conditions may have been exacerbated by orographic features of the study area. That is, pairs at higher elevations (MOA sites) and on more marginal or exposed cliffs, might have experienced more severe weather. Weather data from the periphery of the region indicates that Fairbanks (150 m [492 ft] ASL) is warmer and drier during summer than Eagle (250 m [820 ft] ASL), suggesting that orographic features increase the amount of precipitation and lower temperatures as elevation increases. Weather records (1997 and 1998) from a mine site on the Goodpaster River at a higher elevation (~425 m [1394 ft]) were more variable. Temperatures were lower than Fairbanks and Eagle for both years, as predicted, but only one of the two years (1997) had greater precipitation.

The adverse effects of weather, particularly spring conditions, on nesting raptors have been reported frequently (Mearns and Newton 1984, 1988; Court et al. 1988; Olsen and Olsen 1989; Emison et al. 1993). Impacts include reduced nest-site availability, decreases in prey abundance or hunting efficiency, and embryo and nestling mortality (Newton 1979). In arctic Canada, researchers found that severe weather shortly after clutch completion (mid-June) reduced nesting success (45%) and increased nestling mortality (0.54 young/total pair; Court et al. 1988). These weather conditions were substantially more severe, however, than were weather conditions in east-central Alaska in 1995–1997. Olsen and Olsen (1988, 1989) noted fewer occupied sites during a wet spring and suggested that peregrines might not lay eggs at sites with wet ledges.

It is difficult to determine whether the slightly lower productivity for the MOAs compared to the Tanana River reflects real differences in productivity between these regions, or differences caused by the efficiency of aerial versus ground sampling protocols. Some authors have noted that helicopter surveys are not as accurate as ground surveys because occupied sites likely are missed more often and the number of young are more often incorrectly counted from helicopters (Bromley and Matthews 1988). So, even if the error is similar among areas surveyed from aircraft, the degree of error might differ from a ground survey like those conducted by boat on the Tanana River. Ground visits provide observers with the advantage of hearing birds vocalize, an important cue for locating birds. In addition, ground locations

often provide a better vantage point from which to count young. To offset these limitations of aerial surveys, we made special efforts to enumerate entire broods, often landing to investigate from the ground if we were not sure all young were visible. We also did not include partial brood counts in our measures of productivity, although these sites still were considered successful. We think our efforts reduced potential differences in accuracy between these survey types, but more intensive ground-truthing would be necessary to eliminate this potential error.

Peregrine populations were reduced substantially in east-central Alaska by the mid 1970s due to indiscriminant use of pesticides in the 1950s and 1960s (Ambrose et al. 1988). Only a few individuals remained on the Tanana River and no successful breeding was detected in 1975 (Haugh 1976). At the same time, the number of pairs on the Yukon River between Eagle and Circle was reduced to about half of the number recorded before 1970 (Cade et al. 1976, Ambrose et al. 1988). The few surveys that were conducted in the MOAs (exclusive of the upper Yukon River) indicated, with few exceptions (e.g., Charley River, Cade 1976), none or only the occasional peregrine and no definite breeding records (Center for Northern Studies 1976, Haugh 1976, Haugh and Halperin 1976). A similarly timed assessment of population status in northern Alaska (Colville River, Cade and White 1976) provided evidence that declines on tributaries were more pronounced than along major rivers. If this phenomenon occurred in east-central Alaska, it is probable that the numbers of Peregrine Falcons at MOA sites were reduced substantially and that nesting pairs may have been nearly extirpated along the smaller drainages by the mid-1970s.

By the early 1980s, peregrines had increased substantially along the major rivers of east-central Alaska (Ambrose et al. 1988, White et al. 1990, Enderson et al 1995). Annual monitoring programs in Alaska established a good record of the recovery of peregrines in east-central Alaska showing continued increasing trends in numbers of birds to the present (Figure 2.4; Ambrose 1995, Bente and Wright 1995; McIntyre 1996; Ritchie and Rose 1998b). Productivity also has regularly exceeded goals of the recovery plan (USFWS 1982) and has been at levels allowing more than adequate recruitment into the breeding populations of these major rivers. Surplus birds could provide sources for recolonization in more remote areas. Banding studies have shown that some birds can disperse >100 km (62 mi; Ambrose and Riddle 1988), which is well within the reach of all MOA sites. Peregrines banded on the Yukon or Tanana rivers (black bands) were observed at one site on the Black River in 1985 (Ritchie 1984) and at 2 of 14 remote sites checked in 1997 (unpublished notes) providing recent evidence of immigration from major rivers.

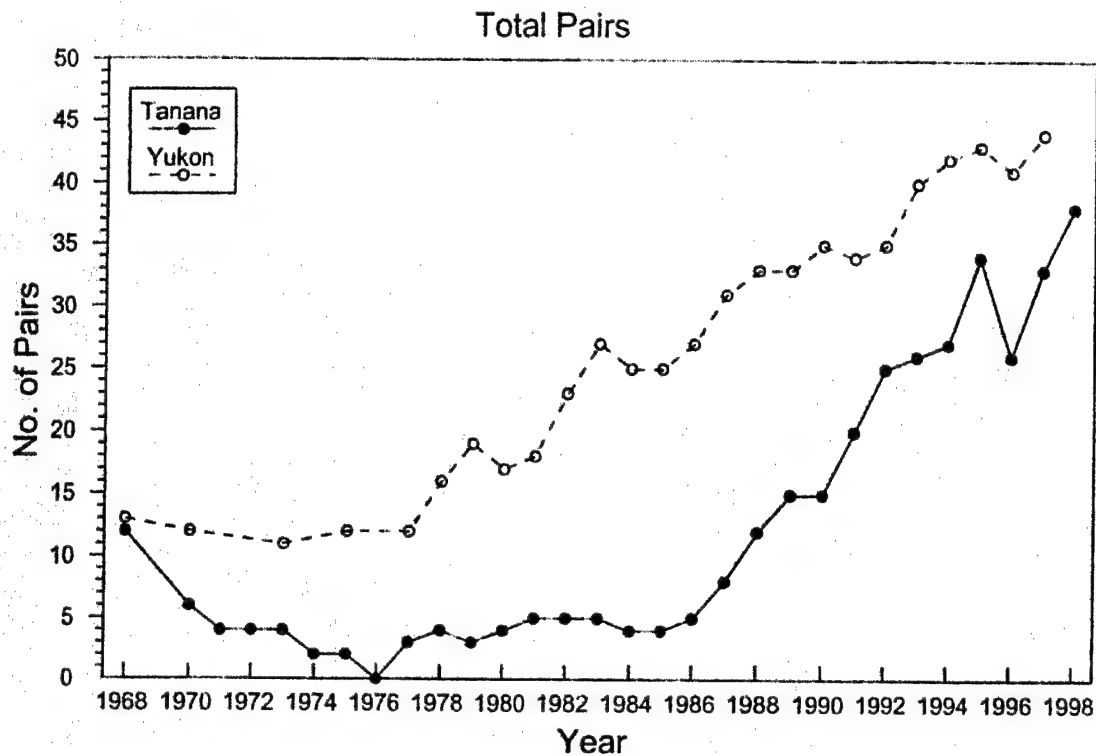


Figure 2.4. *Numbers of pairs of Peregrine Falcons recorded along monitoring sections of the upper Yukon and Tanana Rivers, east-central Alaska, 1968–1998.*

Unfortunately, few data are available to develop a picture of how all MOA sites in east-central Alaska were recolonized. The first good post-decline records of peregrines in the remote areas of the MOAs were not collected until the mid-1980s. At that time, a few sites were found occupied on major tributaries like the Black (Ritchie 1984), Charley (McIntyre 1996), Fortymile (unpublished notes, USFWS), and Kandik (Swem 1984) rivers. No intensive surveys were conducted on smaller drainages (e.g., Salcha and Goodpaster rivers) until the 1990s.

Our data suggest that the rate of increase at MOA sites is substantially higher than current rates of increase recorded for the main rivers, where nesting habitats appear to be more saturated. Recent occupation by peregrine pairs of quarried sections of the Alaska Highway adjacent to the upper Tanana River, where most natural cliffs along the river already are occupied, attest to the more limited expansion potential for the Tanana River population (Ritchie et al. 1998b). Thus, the recovery process may be in an earlier stage at MOA sites compared to sites along main rivers and, at present, availability of nesting sites

does not appear to be a limiting factor. Finally, observations of subadult birds at cliffs are common in expanding populations, whereas they are unusual in more stable populations (Mearns and Newton 1988). We observed at least 3 subadult females in the upper Seventymile and Fortymile rivers in 1995 alone.

In summary, the peregrine population in remote areas has increased substantially during the brief period of our study, particularly between 1995 and 1996, but caution should be exercised when interpreting these short-term results. Along the MacKenzie River, NWT, Bromley and Matthews (1988) showed that fluctuations in the peregrine population, if viewed in the context of 3 to 4 years of data, would have shown steep declines or steep increases depending entirely on the period of years selected for review! An understanding of the nature of these increases in peregrine populations—short-term, or long-term phenomena—in the study area will require longer term monitoring of peregrine sites in the region.

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Appendix 2-A Dates and types of surveys for Peregrine Falcons in Yukon MOAs 1 through 5 and along the Tanana River, east-central Alaska, 1994–1998.

Year	Dates	Regions	Survey type	Aircraft or boat
1994	11, 16–19 May	MOAs 1–3, 5	Occupancy	PA-18 Supercub
	13, 15, 17, 23 July	MOAs 1, 5	Productivity	PA-18 Supercub
	18, 21–22 July	MOAs 1–3	Productivity	Bell 206B aircraft
1995	17–20 May	Tanana River	Occupancy	Zodiac raft
	23–29 May, 2 June	MOAs 1–4	Occupancy	Hughes 500D aircraft
	13–15 July	Tanana River	Productivity	Zodiac raft
	15–18 July, 28 August	MOAs 1–4	Productivity	Bell 206 B aircraft
1996	20–24 May	Tanana River	Occupancy	Zodiac raft
	26–31 May, 1–2 June	MOAs 1–3	Occupancy	Hughes 500D aircraft
	5–10, 19 July	Tanana River	Productivity	Zodiac raft
	12–16 July	MOAs 1–3, 5	Productivity	Hughes 500D aircraft
1997	18–23 May, 13 June	Tanana River	Occupancy	Riverboat with jet outboard
	25–31 May, 1 June	MOAs 1–3	Occupancy	Hughes 500D aircraft
	5–10, 19 July	Tanana River	Productivity	Zodiac raft
	12–17 July	MOAs 1–3	Productivity	Hughes 500D aircraft
1998	22, 23 May	Tanana River	Occupancy	Zodiac raft
	24–28 May, 2,3,7 June	MOAs 1–2	Occupancy	Bell 206B aircraft
	4, 9, 13–15 July	Tanana River	Productivity	Zodiac raft
	6, 7, 10 July	MOAs 1–2	Productivity	Bell 206 and Hughes 500D aircraft

Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

Location	Nest	Drainage	STAT94	STAT95-1	STAT95-2	STAT96-1	STAT96-2	STAT97-1	STAT97-2	STAT98-1	STAT98-2	Latitude	Longitude
TANANA	93.5	Tanana	nd	pair	pair	nd	nd	unoccup.	ns	single ad	unoccup.	63.3830	142.6917
TANANA	103	Tanana	nd	pair	3 yg	ns	2 yg	pr(inc)	2 yg	pr(inc)	2 yg	63.3650	142.8222
TANANA	135	Tanana	nd	pair	pair	ns	single ad	unoccup.	unoccup.	single ad	pair	63.4235	143.1387
TANANA	181	Tanana	nd	pr (inc)	3 yg	ns	unoccup.	pr(inc)	1 yg	pr(inc)	4 yg	63.4097	143.6013
TANANA	205	Tanana	nd	pr (inc)	3 yg	pr(inc)	single ad	pair	2 yg	pr(inc)	3 yg	63.4938	143.7883
TANANA	211	Tanana	nd	pair	4 yg	pr	pr	single ad	single ad	unoccup.	3 yg	63.5482	143.7738
TANANA	221.5	Tanana	nd	pr (inc)	2 yg	pr(inc)	4 yg	pr(inc)	3 yg	pr(inc)	4 yg	63.6097	143.8250
TANANA	243	Tanana	nd	pr (inc)	2 yg	pr(inc)	unoccup.	pr(inc)	2 yg	pr(inc)	4 yg	63.7203	144.1043
TANANA	244.5	Tanana	nd	unoccup.	pair	unoccup.	single ad	pair	2 yg	single ad	4 yg	63.7195	144.1255
TANANA	247	Tanana	nd	pr (inc)	2 yg	ns	1 yg	unoccup.	unoccup.	unoccup.	unoccup.	63.7198	144.1902
TANANA	248	Tanana	nd	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	3 yg	63.7227	144.2036
TANANA	257	Tanana	nd	ns	ns	nd	nd	ns	3 yg	pr(inc)	3 yg	63.7213	144.3187
TANANA	258.5	Tanana	nd	pr (inc)	3 yg	unoccup.	2 yg	pr(inc)	3 yg	pair + subad	2 yg	63.7138	144.3783
TANANA	269.5	Tanana	nd	pr (inc)	3 yg	pr(inc)	4 yg	pr(inc)	2 yg	pr(inc)	2 yg	63.7162	144.5620
TANANA	273	Tanana	nd	single ad	unoccup.	nd	nd	pair	3 yg	pr(inc)	3 yg	63.7228	144.6094
TANANA	280.5	Tanana	nd	pair	2 yg	pr(inc)	3 yg	pair	3 yg	pr(inc)	4 yg	63.7767	144.6907
TANANA	282	Tanana	nd	unoccup.	2 yg	ns	unoccup.	pr(inc)	3 yg	single ad	4 yg	63.7922	144.7367

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Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

TANANA	288.5	Tanana	nd	pr (inc)	4 yg	pr(inc)	2 yg	pair	4 yg	pr(inc)	2 yg	63.8228	144.8048
TANANA	299	Tanana	nd	pair	2 yg	pr	3 yg	single ad	3 yg	pr	4 yg	63.8967	144.8190
TANANA	320	Tanana	nd	pr (inc)	3 yg	pr(inc)	3 yg	pr(inc)	2 yg	pr(inc)	2 yg	64.0222	144.9113
TANANA	335	Tanana	nd	pair	pair	single ad	0	unoccup.	unoccup.	unoccup.	unoccup.	64.0725	145.1328
TANANA	336.5	Tanana	nd	pr (inc)	4 yg	pr	single ad	single ad	pair	pr(inc)	2 yg	64.0612	145.1467
TANANA	371	Tanana	nd	unoccup.	unoccup.	pr	2 yg	pr(inc)	3 yg	pr(inc)	3 yg	64.1663	145.6357
TANANA	376	Tanana	nd	pr (inc)	4 yg	pr	3 yg	unoccup.	4 yg	pr(inc)	3 yg	64.1912	145.6763
TANANA	380	Tanana	nd	pr (inc)	4 yg	pr(inc)	3 yg	pr(inc)	1 yg	pr(inc)	4 yg	64.1837	145.7560
TANANA	386	Tanana	nd	pair	pair	pr?	unoccup.	3 adults	unoccup.	single ad	3 yg	64.1572	145.8592
TANANA	405	Tanana	nd	ns	ns	ns	0	ns	2 yg	pr(inc)	1 yg	64.2620	146.1073
TANANA	408	Tanana	nd	pair	pair	pr	2 yg	pr(inc)	3 yg	pr(inc)	3 yg	64.2477	146.1958
TANANA	414.5	Tanana	nd	pr (inc)	3 yg	unoccup.	4 yg	unoccup.	2 yg	pr(inc)	4 yg	64.2588	146.2840
TANANA	427	Tanana	nd	pr (inc)	3 yg	pr(inc)	3 yg	pr(inc)	2 yg	pr(inc)	pair	64.2815	146.5253
Location	Nest	Drainage	STAT94	STAT95-1	STAT95-2	STAT96-1	STAT96-2	STAT97-1	STAT97-2	STAT98-1	STAT98-2	Latitude	Longitude
TANANA	431	Tanana	nd	pr (inc)	3 yg	pr(inc)	pr	pr(inc)	4 yg	pr(inc)	3 yg	64.2690	146.5947
TANANA	436.5	Tanana	nd	pr (inc)	2 yg	pr(inc)	1 yg	pr(inc)	pair	pr(inc)	2 yg	64.2765	146.6800
TANANA	438.5	Tanana	nd	single ad	single ad	pr(inc)	2 yg	pair	single ad	pr(inc)	pair	64.2925	146.7013
TANANA	443	Tanana	nd	pair	pair	pr(inc)	unoccup.	single ad	2 yg	pr(inc)	2 yg	64.3178	146.7693

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yg = brood size (number of young in the nest) at the time the nest site was surveyed

Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

TANANA 449	Tanana	nd	ns	ns	ns	ns	ns	ns	single ad	single ad	64.3395	146.8512
TANANA 459.5	Tanana	nd	pair	pair	ns	single ad	single ad	single ad	pr(inc)	single ad	64.4077	146.9667
TANANA 470.5	Tanana	nd	ns	ns	ns	ns	ns	1 yg	unoccup.	single ad	64.4787	146.9759
TANANA 550	Tanana	nd	pr(inc)	3 yg	ns	ns	pr(inc)	pair	pr(inc)	2 yg	64.7562	148.0310
TANANA 551.5	Tanana	nd	ns	ns	ns	ns	pr(inc)	4 yg	pr(inc)	4 yg	64.7498	148.0613
TANANA 578	Tanana	nd	ns	ns	ns	ns	unoccup.	single ad	pr(inc)	1 yg	64.6649	148.4142
TANANA 586	Tanana	nd	pr(inc)	3 yg	ns	ns	pr(inc)	1 yg	pr	1 yg	64.6499	148.5533
TANANA 610	Tanana	nd	pr(inc)	ns	ns	ns	pair	3 yg	pr	pair	64.5836	148.8741
YUK 1 1001	Salcha	single ad	pr (inc)	ad+ eggs	pr(inc)	4 yg	pr(inc)	3 yg	pr(inc)	2 yg	64.7667	145.3232
YUK 1 1002	Salcha	unoccup.	unoccup.	ns	unoccup.	unoccup.	unoccup.	ns	pr	2 yg	64.9500	145.1725
YUK 1 1003	Salcha	unoccup.	unoccup.	unoccup.	ad(inc)	eggs	unoccup.	1 yg	unoccup.	unoccup.	64.8590	144.5168
YUK 1 1004	Salcha	pair	pr (inc)	2 yg	pr(inc)	4 yg	pr(inc)	3 yg	pr(inc)	3 yg	64.6582	144.9862
YUK 1 1005	Salcha	1 yg	unoccup.	single ad	pr(inc)	1 yg	single ad	unoccup.	single ad	unoccup.	64.6717	144.7000
YUK 1 1006	Goodpaster	3 yg	unoccup.	unoccup.	single ad	pr	pair	2 yg	pr(inc)	2 yg	64.3378	145.0927
YUK 1 1007	Goodpaster	3 yg	pr (inc)	4 yg	pr(inc)	4 yg	pr(inc)	single ad	pr(inc)	2 yg	64.3087	145.1112
YUK 1 1008	Salcha	unoccup.	pr (inc?)	pr display	single ad	single ad	pr(inc)	3 yg	pr(inc)	2 yg	64.8932	144.4283
YUK 1 1009	Salcha	unoccup.	single ad	single ad	unoccup.	pr	pr(inc)	2 yg	single ad	unoccup.	64.7010	144.8713
YUK 1 1010	Salcha	unoccup.	single ad	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	pr	unoccup.	64.5370	145.4097

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Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

YUK 1	1020	Salcha	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	pr(inc)	3 yg	64.7602	144.4772
YUK 1	1021	Salcha	unoccup.	pr(inc)	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	64.8463	144.5425
YUK 1	1040	Healy	unoccup.	ns	ns	single ad	unoccup.	ns	ns	ns	64.0152	144.3012
YUK 1	1041	Healy	unoccup.	ns	ns	pr(inc)	2 yg	ns	ns	ns	64.1150	143.9675
YUK 1	1043	Goodpaster	unoccup.	unoccup.	unoccup.	ad(inc)	3 yg	pr(inc)	3 yg	pr(inc)	64.5042	144.5167
YUK 1	1049	Goodpaster	ns	ns	ns	unoccup.	3 yg	pr(inc)	single ad	pr	64.3867	144.9157
YUK 1	1051	Salcha	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	pr	unoccup.	64.9748	145.1485
YUK 1	1054	Salcha	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	ns	64.6413	145.0835
YUK 9	1055	Salcha	ns	ns	ns	ns	ns	ns	pr(inc)	unoccup.	64.5672	146.2375
YUK 9	1056	Salcha	ns	ns	ns	ns	ns	ns	pr(inc)	unoccup.	64.4930	146.5582
Location	Nest	Drainage	STAT94	STAT95-1	STAT95-2	STAT96-1	STAT96-2	STAT97-1	STAT97-2	STAT98-1	Latitude	Longitude
YUK 9	1057	Salcha	ns	ns	ns	ns	ns	ns	pair	pr(inc)	64.4742	146.7433
YUK 9	1058	Salcha	ns	ns	ns	ns	ns	ns	single ad	unoccup.	64.4757	146.8568
YUK 1	1060	Charley	ns	ns	ns	ns	ns	ns	single ad	unoccup.	64.9672	143.6108
YUK 1	1061	Charley	ns	ns	ns	ns	ns	ns	4 yg	ns	64.8065	143.4950
YUK 1	1062	Charley	ns	ns	ns	ns	ns	ns	2 yg	ns	64.8544	143.3051
YUK 1	1063	Charley	ns	ns	ns	ns	ns	ns	pair	ns	64.8320	143.1709
YUK 1	1064	Charley	ns	ns	ns	ns	ns	ns	single ad	ns	64.7124	143.6431

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Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

YUK 9	1065	Goodpaster	ns	ns	ns	3 yg	ns	4 yg	pr(inc)	1 yg	64.1152	145.2027
YUK 1	1074	Goodpaster	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	pr(inc)	pr(inc)	64.4672	144.9123
YUK 1	1075	Salcha	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	pr(inc)	2 yg	64.6468	145.3980
YUK 2	2001	Birch Creek	1 yg	pr(inc)	4 yg	pr	4 yg	pr(inc)	pr(inc)	3 yg	65.8202	144.2918
YUK 2	2002	Birch Creek	3 yg	ad(inc)	3 yg	pr(inc)	4 yg	unoccup.	pr(inc)	4 yg	65.7540	144.3570
YUK 2	2003	Birch Creek	single ad	ad(inc)	3 yg	pr	0	single ad	pr(inc)	3 yg	65.3627	144.2847
YUK 2	2004	Birch Creek	1 yg	pr(inc)	3 yg	pr(inc)	2 yg	3 adults	pr(inc)	1 yg	65.3207	144.4118
YUK 2	2005	Birch Creek	pair	pr(inc)	2 yg	pr(inc)	0	pr(inc)	unoccup.	unoccup.	65.3427	144.8412
YUK 2	2006	Birch Creek	single ad	unoccup.	unoccup.	ad+egg	0	single ad	unoccup.	unoccup.	65.3073	144.4652
YUK 2	2007	Birch Creek	single ad	pr(inc)	ad+eggs	pr(inc)	ad+eggs	1 yg	pr(inc)	pr(inc)	65.3293	144.5317
YUK 2	2008	Birch Creek	unoccup.	unoccup.	single ad	0	single ad	unoccup.	pr(inc)	single ad	65.2230	144.2740
YUK 2	2009	Birch Creek	unoccup.	unoccup.	single ad	pr(inc)	1 yg	single ad	pr(inc)	3 yg	65.2558	144.3583
YUK 2	2010	Black River	2 yg	ns	ns	ns	2 yg	ns	ns	ns	65.6900	143.0507
YUK 2	2015	Birch Creek	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	pr(inc)	unoccup.	unoccup.	65.2250	144.3292
YUK 2	2016	Birch Creek	unoccup.	pr(inc)	2 yg	pr(inc)	dead yg	pair	pr(inc)	2 yg	65.3037	145.0283
YUK 2	2023	Birch Creek	ns	ns	ns	pr(inc)	3 yg	pr(inc)	pr	2 yg	65.7175	144.7135
YUK 2	2024	Birch Creek	ns	ns	ns	pr(inc)	3 yg	single ad	pr(inc)	3 yg	65.7155	144.7895
YUK 2	2025	Birch Creek	ns	ns	ns	ad(inc)	3 yg	pr(inc)	pr(inc)	3 yg	65.8015	144.8070

a

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Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

YUK 2	2026	Birch Creek	ns	ns	ns	pr	unoccup.	single ad	unoccup.	pr(inc)	1 yg	65.7765	145.4067
YUK 2	2027	Birch Creek	ns	ns	ns	single ad	single ad	pr(inc)	3 yg	pr	2 yg	65.6968	145.1207
YUK 2	2028	Birch Creek	ns	ns	ns	pr(inc)	2 yg	pr(inc)	3 yg	pr	2 yg	65.6922	145.0565
YUK 2	2029	Birch Creek	ns	unoccup.	unoccup.	pr	2 yg	pr(inc)	pair	pr	unoccup.	65.1453	145.4850
YUK 2	2030	Birch Creek	unoccup.	unoccup.	unoccup.	pr	unoccup.	pr(inc)	3 yg	pr	pair	65.3585	144.6950
YUK 2	2032	SF Birch Creek	unoccup.	unoccup.	unoccup.	pr(inc)	2 yg	pr(inc)	2 yg	unoccup.	unoccup.	65.2953	144.4213
YUK 2	2033	SF Birch Creek	unoccup.	unoccup.	unoccup.	single ad	unoccup.	unoccup.	unoccup.	unoccup.	unknown	65.2045	144.0837
Location	Nest	Drainage	STAT94	STAT95-1	STAT95-2	STAT96-1	STAT96-2	STAT97-1	STAT97-2	STAT98-1	STAT98-2	Latitude	Longitude
YUK 2	2038	Black	ns	ns	ns	3 yg	3 yg	ns	ns	ns	ns	65.6058	143.1277
YUK 2	2040	Birch Creek	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	pr(inc)	3 yg	pr(inc)	3 yg	65.3427	144.6242
YUK 3	2041	Birch Creek	ns	ns	ns	ns	ns	unoccup.	unoccup.	pr	1 yg	65.3030	144.4300
YUK 4	2042	Yukon	ns	ns	ns	ns	ns	ns	ns	pr(inc)	unoccup.	65.7497	144.0800
YUK 5	2043	Coal Creek	ns	ns	ns	ns	ns	ns	ns	pr(inc)	unoccup.	65.2847	143.2123
YUK 6	2045	Woodchopper	ns	ns	ns	ns	ns	ns	ns	pr(inc)	1 yg	65.3268	143.3348
YUK 7	2047	Yukon	ns	ns	ns	ns	ns	ns	ns	single ad	unoccup.	65.7300	144.1207
YUK 3	3001	Seventymile	single ad	unoccup.	unoccup.	unoccup.	ns	pr(inc)	3 yg	ns	ns	64.9000	141.3083
YUK 3	3002	Seventymile	2 yg	pair (inc?)	single ad	unoccup.	1+yg	single ad	unoccup.	ns	ns	64.9030	141.6148
YUK 3	3003	Seventymile	1 yg	single ad	3 yg	unoccup.	single ad	pr(inc)	unoccup.	ns	ns	64.9303	141.7340

^a

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Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

YUK 3	3004	Seventymile	1 yg	pr (inc)	3 yg	ad(inc)	4 yg	unoccup.	unoccup.	ns	64.9862	142.2008
YUK 3	3005	Seventymile	pair	single ad	unoccup.	pr(inc)	2 yg	single ad	unoccup.	ns	64.9963	142.3173
YUK 3	3006	Seventymile	pair	unoccup.	3 yg	unoccup.	3 yg	pr(inc)	2 yg	ns	64.8913	142.2802
YUK 3	3007	Fortymile	pair	pr (inc)	ad + egg	single ad	2 yg	pair	2 yg	ns	64.4345	143.2422
YUK 3	3008	Fortymile	3 yg	single ad	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	ns	64.6158	142.2008
YUK 3	3009	Fortymile	pair	pr (inc)	2 yg	pr(inc)	2 yg(egg)	pr(inc)	2 yg	ns	64.0710	142.0167
YUK 3	3010	Seventymile	1 yg	pr (inc)	3 yg	single ad	2 yg	pr(inc)	unoccup.	ns	64.7072	141.5402
YUK 3	3015	Fortymile	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	pr(inc)	unoccup.	ns	64.6118	142.2007
YUK 3	3022	Seventymile	unoccup.	pr (inc)	3 yg	ad(inc)	2 yg	pr(inc)	3 yg	ns	64.9317	141.8268
YUK 3	3023	Seventymile	unoccup.	pr(subad)	unoccup.	unoccup.	unoccup.	unoccup.	unoccup.	ns	64.9790	141.9902
YUK 3	3024	Seventymile	ns	pair	single ad	ad(inc)	2 yg	pr(inc)	2 yg	ns	64.8483	141.8393
YUK 3	3025	Seventymile	ns	pr (inc)	2 yg	pr(inc)	2 yg	pr(inc)	single ad	ns	64.8867	141.5568
YUK 3	3027	Fortymile	ns	single ad	ns	pr(inc)	2 yg	pr(inc)	2 yg	ns	64.4698	142.2568
YUK 3	3028	Fortymile	ns	pr(subad)	ns	unoccup.	unoccup.	ad(inc)	1 egg	ns	64.4690	142.5268
YUK 3	3029	Fortymile	ns	pair	ns	unoccup.	unoccup.	pr(inc)	1 yg	ns	64.4592	142.6365
YUK 3	3030	Fortymile	ns	pr (inc)	2 yg	pr(inc)	2 yg	unoccup.	unoccup.	ns	64.4572	142.6678
YUK 3	3031	Fortymile	ns	pair	ns	unoccup.	unoccup.	pr(inc)	1 yg	ns	64.4018	142.8158
YUK 3	3032	Fortymile	ns	pr (inc)	ns	pr(inc)	1 yg	unoccup.	2 yg	ns	64.3862	142.8862

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Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

YUK 3	3033	Seventymile	unoccup.	unoccup.	ad+dead yg	unoccup.	pr(inc)	1 yg	ns	ns	64.9700	142.0793
YUK 3	3045	Seventymile	unoccup.	unoccup.	unoccup.	pr(inc)	2 yg	unoccup.	ns	ns	64.9568	141.9765
YUK 3	3046	Seventymile	unoccup.	unoccup.	unoccup.	single ad	unoccup.	ns	ns	ns	64.7902	141.4812
YUK 3	3049	Fortymile	unoccup.	unoccup.	unoccup.	pr(inc)	unoccup.	3 yg	ns	ns	64.4700	142.2042
YUK 3	3050	Fortymile	ns	unoccup.	unoccup.	pr(inc)	2 yg	3 yg	ns	ns	64.5537	142.0367
YUK 3	3051	Fortymile	unoccup.	unoccup.	unoccup.	single ad	unoccup.	unoccup.	ns	ns	64.5890	142.1648
YUK 3	3052	Fortymile	unoccup.	unoccup.	unoccup.	pr(inc)	2 yg	single ad	ns	ns	64.6210	142.2573
YUK 3	3054	Fortymile	unoccup.	unoccup.	unoccup.	pr(inc)	3 yg	1 yg	ns	ns	64.4757	142.3275
YUK 3	3058	Fortymile	ns	ns	ns	ns	2 yg	pair	ns	ns	64.6773	142.0782
YUK 3	3059	Fortymile	unoccup.	unoccup.	unoccup.	ns	2 yg	unoccup.	ns	ns	64.4763	142.4807
YUK 3	3060	Seventymile	unoccup.	unoccup.	unoccup.	unoccup.	2 yg	single ad	ns	ns	64.9695	142.1342
YUK 3	3063	Fortymile	ns	ns	ns	ns	ns	3 adults	ns	ns	64.4545	142.2050
YUK 3	3066	Fortymile	ns	ns	ns	ns	ns	single ad	ns	ns	64.4415	142.0958
YUK 3	3067	Fortymile	ns	ns	ns	ns	ns	2 yg	ns	ns	64.3833	142.0250
YUK 3	3069	Fortymile	ns	ns	ns	ns	ns	1 yg	ns	ns	64.3468	142.0070
YUK 3	3070	Fortymile	ns	ns	ns	ns	ns	2 yg	ns	ns	64.3403	141.9910
YUK 3	3071	Fortymile	ns	ns	ns	ns	ns	unoccup.	ns	ns	64.3032	141.9627
YUK 3	3072	Fortymile	ns	ns	ns	ns	ns	3 yg	ns	ns	64.4772	142.2167

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Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

YUK 3	3073	Fortymile	ns	ns	ns	ns	1 yg	ns	ns	64.3723	143.1590
YUK 3	3074	Fortymile	ns	ns	ns	ns	2 yg	ns	ns	64.0097	141.9797
YUK 3	3075	Fortymile	ns	ns	ns	ns	3 yg	ns	ns	64.0985	141.7572
YUK 3	3076	Fortymile	ns	ns	ns	ns	pair	ns	ns	64.1331	141.7790
YUK 3	3077	Fortymile	ns	ns	ns	ns	pair	ns	ns	64.1737	141.7459
YUK 3	3078	Fortymile	ns	ns	ns	ns	2 yg	ns	ns	64.2014	141.7405
YUK 3	3079	Fortymile	ns	ns	ns	ns	single ad	ns	ns	64.2118	141.7685
YUK 3	3080	Fortymile	ns	ns	ns	ns	pair	ns	ns	64.2282	141.7864
YUK 3	3081	Fortymile	ns	ns	ns	ns	pair	ns	ns	64.2718	141.6959
YUK 3	3082	Fortymile	ns	ns	ns	ns	3 yg	ns	ns	64.2943	141.6260
YUK 3	3083	Fortymile	ns	ns	ns	ns	3 yg	ns	ns	64.3004	141.4912
YUK 3	3084	Fortymile	ns	ns	ns	ns	pair	ns	ns	64.2707	141.8238
YUK 3	3085	Seventymile	ns	ns	ns	ns	single ad	ns	ns	64.9730	142.8102
YUK 3	3086	Seventymile	ns	ns	ns	ns	3 yg	ns	ns	64.9970	142.5691
YUK 4	4001	Nation	ns	single ad	ns	ns	ns	ns	ns	65.5133	141.0258
YUK 4	4002	Nation	ns	pr (inc)	2 yg	ns	ns	ns	ns	65.4202	141.3855
YUK 4	4003	Kandik	ns	single ad	ns	ns	ns	ns	ns	65.5227	141.7100
YUK 4	4004	Kandik	ns	pr (inc)	3 yg	ns	ns	ns	ns	65.5562	141.5535

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pr (inc) = two adults detected near the nest site, one sitting on the nest
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Appendix 2-B Peregrine falcon nest sites and status, Tanana River and Yukon MOAs 1 through 5, east-central Alaska, 1994-1998.^a

Location	Nest	Drainage	STAT94	STAT95-1	STAT95-2	STAT96-1	STAT96-2	STAT97-1	STAT97-2	STAT98-1	STAT98-2	Latitude	Longitude
YUK 4	4005	Nation	unoccup.	single ad	ns	ns	ns	ns	ns	ns	ns	65.5847	141.5075
YUK 4	4006	Black	2 yg	ns	ns	ns	4 yg	ns	ns	ns	ns	66.1878	142.1862
YUK 4	4010	Black	ns	ns	ns	ns	2 yg	ns	ns	ns	ns	66.1718	141.3962
YUK 4	4011	Black	unoccup.	ns	ns	ns	1 yg	ns	ns	ns	ns	65.7072	142.0388
YUK 5	5001	Black	1 yg	ns	ns	ns	ns	ns	ns	ns	ns	66.6772	142.1707
YUK 5	5002	Black	single ad	ns	ns	ns	ns	ns	ns	ns	ns	66.4958	142.4033
YUK 5	5003	Black	3 yg	ns	ns	ns	ns	ns	ns	ns	ns	66.6053	142.8273
YUK 5	5004	Black	2 yg	ns	ns	ns	ns	ns	ns	ns	ns	66.7058	143.0845
YUK 5	5005	Black	3 yg	ns	ns	ns	ns	ns	ns	ns	ns	66.6843	143.5055
YUK 5	5042	Black	unoccup.	ns	ns	ns	1 yg	ns	ns	ns	ns	66.4722	141.4087

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pr (inc) = two adults detected near the nest site, one sitting on the nest

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CHAPTER 3

ANIMAL NOISE MONITOR (ANM) SPECIFICATIONS AND PERFORMANCE AT PEREGRINE FALCON NEST SITES WITHIN U.S. AIR FORCE MILITARY OPERATIONS AREAS ON THE TANANA RIVER, ALASKA

Michael D. Smith, Stephen M. Murphy, Ann E. Bowles, & B. Andrew Kugler

INTRODUCTION

Reduced public acceptance of U.S. Air Force (USAF) training exercises in populated areas has resulted in increased use of airspace over remote public lands, which has led to increased exposure of wildlife to high levels of noise. Concerns about the effects of military training exercises on wildlife prompted the U.S. USAF and the U.S. Fish and Wildlife Service (USFWS) to conduct a workshop in 1988 to identify potential research programs for understanding the responses of wildlife to noise (Asherin and Gladwin 1988). Historically, field studies of aircraft effects on wild animals have not collected noise exposure data because of the difficulty of measuring noise near free-ranging animals. One recommendation that found broad support at the workshop was development of monitors that could quantify noise experienced by free-ranging animals.

On the strength of this recommendation, the USAF developed a prototype Personal Noise Monitor (PNM) for animals and its successor, the Animal Noise Monitor (ANM; produced by Wildlife Computers, Redmond, WA). These small instruments were designed to collect event-related sound exposure data that could be deployed in large numbers under field conditions (e.g., at nesting sites or on large mammals instrumented with collars). Although the ANM has limited capabilities and less precision than is usual for such instruments (it is rated as a Type III instrument), it was felt that the advantage of collecting noise data from a large number of animals at their exact location and over a long period (months) far outweighed the disadvantages of imprecision.

This paper describes the technical specifications, user-settable threshold parameters, types of data collected by the instrument, and the results of a study that used ANMs to monitor noise near Peregrine Falcon (*Falco peregrinus anatum*) nests exposed to military aircraft in east-central Alaska.

STUDY AREA

The study area included Yukon Military Operations Areas (MOAs) 1-5 in east-central Alaska and Military Training Routes (MTRs) along the Tanana River between the Tetlin Bridge and the Nenana River (Figure 3.1).

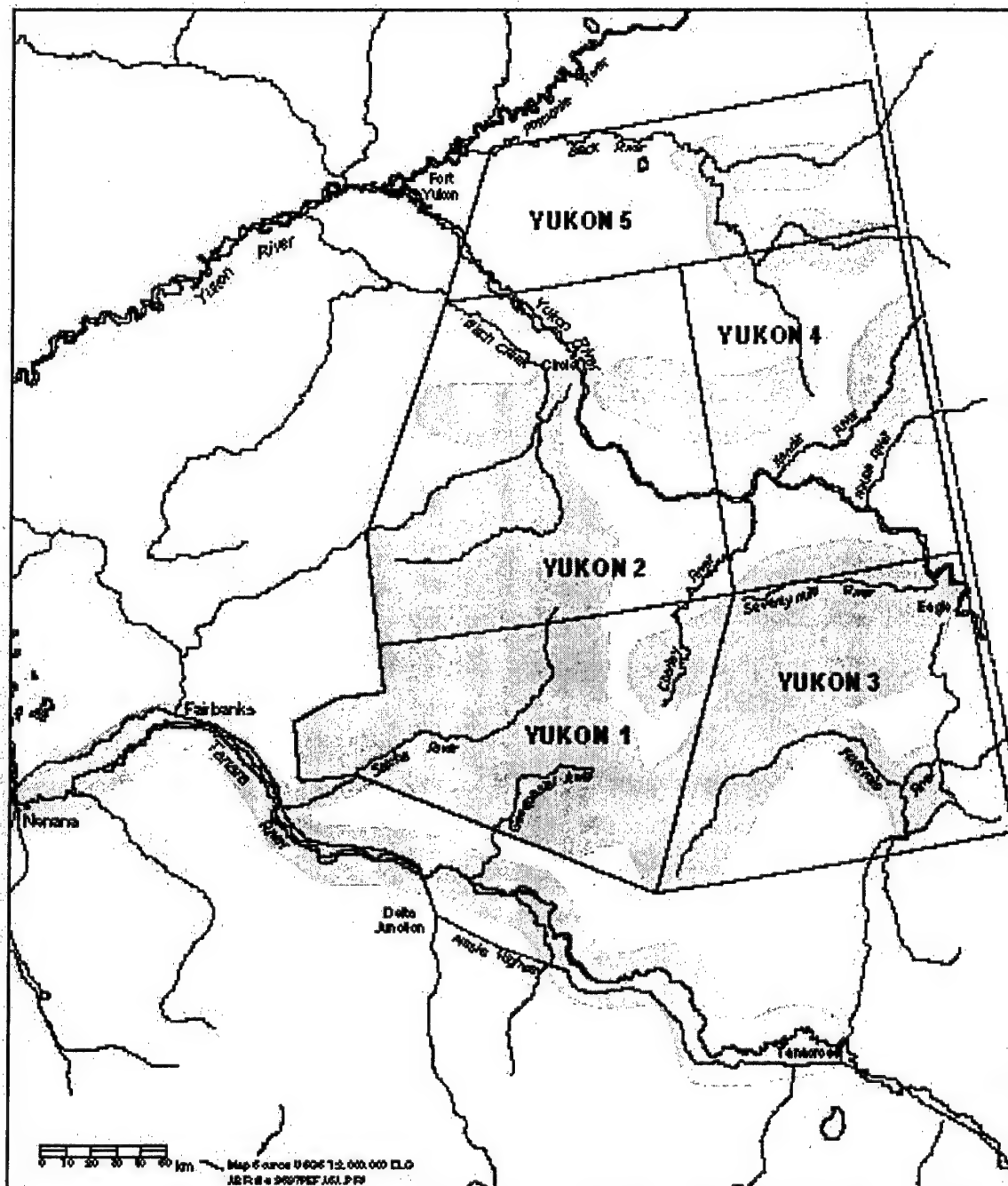


Figure 3.1. Study area for Peregrine Falcon noise disturbance study in east-central Alaska, 1995-1997

It included major drainages, their tributaries, and upland areas in the Yukon-Tanana Uplands and in the Porcupine Plateau between the Yukon and Black rivers. Total area for these watersheds is approximately 62,000 km² (24,800 mi²). Primary drainages for monitoring Peregrine Falcons and deploying ANMs were the Tanana, Salcha, Goodpaster, Fortymile, Seventymile, and Birch. Complete descriptions of the study area and the peregrine populations that inhabit east-central Alaska are provided in Chapters 1 and 2.

METHODS

Design and Specifications of the ANM

The ANM is simple in its basic design, consisting primarily of a microprocessor-controller with a clock/calendar chip, two microphones, flash memory for data storage, a connector to download and upload data, an LED indicator, and a lithium-battery power supply (specifications are listed in Table 3.1; see also Hill 1995, Barber et al. 1995). In addition, it also contains a temperature sensor and a pair of orthogonally-oriented accelerometers. These components are encased in an anodized, aluminum box sealed with rubber O-rings. The data interface port also can be fitted with a plug that disables data collection when the unit is not in use.

Table 3.1. *Specifications of the Animal Noise Monitors (ANMs). Thresholds in parentheses were used in this study.*

Physical Characteristics	Measure or Range	Notes
Dimensions	102 × 70 × 33 mm	anodized aluminum box, sealed with o-rings
Weight	< 150 g	
Power - Lithium C cell	3.0 V	SAFT LSH14
Measurements		
A-weighted SPL ¹	60-120 dBA	
C-weighted SPL	60-120 dBC	
Accelerometer 1 - side-to-side G force	± 1.25 g	
Accelerometer 2 - fore-to-aft G force	± 1.25 g	
Temperature	-20+50°C	
Battery Voltage	0-4.096 V	
Sampling Parameters		
Sampling rate	80/sec	
Sampling interval	12.5 ms	
Threshold Parameters		
Hardware threshold	60-120 dB (75 dBA)	
Sampling threshold	60-120 dB (85 dBA)	set 2-5 dB higher than hardware threshold
Stop threshold	60-120 dB (70 dBA)	set 2-5 dB lower than hardware threshold
Minimum event duration	1+ sec (2 sec)	in 1 sec increments
Maximum time below sampling	1+ sec (5 sec)	in 1 sec increments
Maximum event durations	2-6 min (2 min)	2 min increments
Allowable number of successive too-short sound events	30	
Suspend operation temperature	-20°C	
Restart operation temperature	-17.8°C	
Suspend operation voltage	≤ 2.1 V	

¹ SPL = sound pressure level

Data collected by the ANM are stored in non-volatile flash memory, so that data still can be recovered even if the batteries are completely drained or removed. The unit is programmed using off-the-shelf terminal software (e.g., Hyperterminal) and a serial cable that plugs into the interface port. Data are downloaded in either a verbose text format or in a coded data format that can be interpreted with user-written software to provide standard comma-delimited text suitable for a spreadsheet or database program. ANM data are stored in the form of 13 different records, with 11 records tracking automatic operations, such as errors, changes in threshold, and shut-downs, and the other 2 records storing hourly measurements and sound events.

The ANM is designed to conserve power until a noise event is detected. It has a low-power dormant mode, in which the only active elements are the clock/calendar, memory, low-power microphone, hardware threshold detector, and LED status indicator. These elements draw from a 3-volt (V) lithium battery directly, and they 'listen' continuously until the magnitude of incoming sound pressure exceeds the hardware threshold (see description of thresholds below). The unit also activates at regular intervals to perform routine functions; a status light blinks once per minute to verify that the unit is functioning and baseline accelerometer and noise data are recorded hourly.

When the unit activates for data acquisition (hourly or when the hardware threshold is exceeded), power is boosted to 4-5 V, supplying the main microphone, microprocessor, and accelerometers (activity sensors). When the sampling threshold is exceeded for the minimum time, data acquisition begins. At this time, the status light comes on for 3.2 seconds (sec) to indicate that the unit is recording. Data acquisition continues until the sound pressure drops below the stop threshold or until the maximum time is exceeded. If the maximum time is exceeded, the event is logged as an error to separate wind noise and other longer duration noise from short duration aircraft overflights.

The ANM also is equipped with a pair of accelerometers designed to collect side-to-side and front-to-back movement for studies when the instrument is collar-mounted on an animal. Accelerometer data collection begins during the event and continues afterwards for a time to determine the reaction of the animal. Accelerometer data were not used in this Peregrine Falcon study.

Parameters Collected By the ANM

Weighting networks filter sound in real time to eliminate frequencies that do not contribute significantly to the prediction of noise effects. Chapter 10 describes the rationale for using weighting functions developed for human applications in the study of bird responses to noise. ANMs were designed to filter the sound pressure signal from the instrument's main microphone in real-time using both the A- and C-weighting functions. A-weighting emphasizes frequencies in the human mid-range, which is somewhat wider than a bird's range, and eliminates very low and very high frequencies. This weighting commonly is used when measuring intermittent or continuous noise (e.g., airport noise or traffic noise). In outdoor applications, A-weighting is extremely useful because, when coupled with the use of an appropriate microphone windscreen, it eliminates almost all sound pressure artifacts from wind at low to moderate speeds (<15 knots). C-weighting is flattened relative to A-weighting, and only eliminates very high and low frequency noise; it commonly is used when measuring dosages of impulsive noise, such as sonic booms or blasts.

As described in Chapter 10, the effort to develop sound metrics useful for wildlife applications is still in its infancy. Currently, no agreement has been reached about the most appropriate measures of dosage for birds. Therefore, the ANMs have been designed to store a number of metrics (Table 3.2). Collecting as many metrics as practical makes it more likely that useful ones can be identified during analysis. With a few exceptions (see discussion of thresholds below), the unit has a sampling interval of 125 milliseconds (ms) (i.e., successive samples were 125 ms long).

Table 3.2. Data and noise metrics collected by the Animal Noise Monitors (ANMs).

Informational Records		Interval
date, time, battery voltage	battery temp, threshold settings	hourly
date, time, battery voltage	battery temp, threshold settings, error type	when an error is detected or an event fails to meet criteria
date, time, battery voltage	battery temp, threshold settings, reason for shut-down/activation	when the unit is shut down or re-activated
Event Records		
Start date and time		for every event
Maximum, fast (12.5 ms), A- and C-weighted sound pressure level (L_{max})		12.5 ms 125 ms
Maximum, slow (125 ms) A- and C-weighted sound pressure level (L_{max})		
Event duration in seconds		time between onset and offset
A- and C-weighted sound exposure level (ASEL, CSEL)		between offset and onset (event SEL)
A-weighted onset rate (dB/s). Computed by calculating slope from 5 dB above threshold to 5 dB below the peak.		
C-weighted onset rate (dB/s).		
Battery voltage and temperature		
Envelope, a series of ASEL values (up to 960) collected every 125 ms if the event duration is ≤ 2 min, 250 ms if ≤ 4 min, or 375 ms if ≤ 6 min		within pre-set duration limit
Accelerometer and Background Noise Records		
Readings from both accelerometers and A-weighted sound pressure level (SPL) are taken up to 7 times during the event and once afterwards.		5 sec intervals; 50 sec after event
Background activity and pressure - records from both accelerometers and A-weighted SPL		hourly

The ANM also activates once per hour to collect background (ambient) noise data as 16-byte records. Unfortunately, the dynamic range of the ANM is relatively narrow, with a minimum level detectable by the instrument of 60-65 dBA (decibel, A-weighted), making any background noise data of limited usefulness.

ANM Thresholds

The ANMs are equipped with threshold settings that define the criteria for detecting onset and offset of each noise event (Figure 3.2; also see Table 3.1 for the complete list of all programmed thresholds). The ANMs are equipped with two microphones, a low-power, low-accuracy microphone that samples whenever the ANM is deployed, and a high-power, higher-accuracy microphone that activates whenever the low-power microphone detects a 125 ms sample that exceeds a pre-set *hardware threshold*. This hardware threshold is lower than the *sampling threshold* (typically ~2-5 dB lower) to give the microprocessor and other electronics time to activate and begin sampling. Because of this lag, and because the sampling interval is relatively long (12.5 ms at minimum), event peaks cannot be captured accurately by the device and, therefore, are not recorded. When a noise event exceeds the user-defined sampling threshold, the ANM begins sampling. Sampling continues until a *stop threshold* is reached (generally 5dB lower than the sampling threshold).

Similar thresholds determine the duration of an event. These thresholds prolong battery life and reduce the number of undesired events caused by sound sources that are not of interest (i.e., distant aircraft). Once a sound exceeds the hardware threshold, the ANM continues sampling for a limited time period, determined by the *maximum time below sampling threshold*. Once sound pressure exceeds the sampling threshold, the event must last longer than the *minimum sound event duration* in order to be recorded. Otherwise, an error is recorded. This minimum duration eliminates events triggered by gusts of wind, gunshots, and other short, intense events unrelated to the activity of interest (i.e., aircraft noise). A *maximum sound event duration* threshold eliminates events that are too long. Thresholds used in this study are listed in Table 3.1.

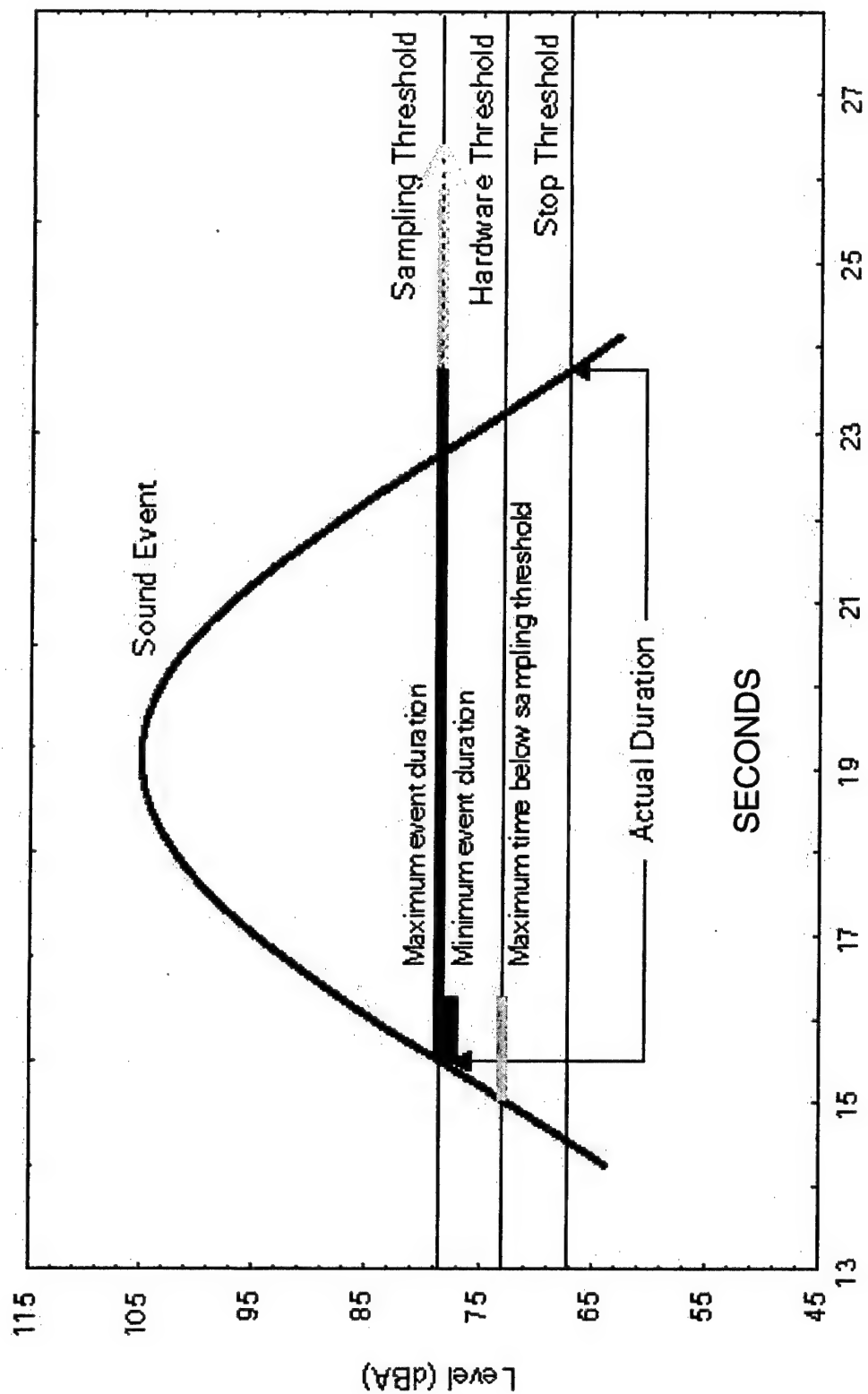


Figure 3.2. Schematic illustration of Animal Noise Monitor (ANM) thresholds. Sound exposure level is measured on the basis of the event duration (actual duration above).

The ANM also has a rudimentary automatic gain control designed to cope with windy conditions or other high background noise. Whenever the hardware threshold is reached, but a sound event is not recorded, an error event is recorded. If wind, for example, causes the background noise level to rise slowly above the hardware threshold but without reaching the sampling threshold within the maximum time allotted, then a timeout error is generated and the ANM boosts all its level thresholds by 5 dB. If thresholds are already at maximum levels, then the unit disables the high-power microphone until the start of the next hour (e.g., if the microphone was disabled at 12:38, the ANM would reset its thresholds to the user-selected levels and enable the high-power microphone at 13:00). The ANM also performs this sequence if it detects too many successive short events or if the maximum event duration is reached. The unit also shuts itself down if its temperature drops below a specified minimum or if the battery drops below a specified voltage. The unit reactivates itself after such a shut-down if internal temperature rises above the minimum by 2.2° C; it does not reactivate after a voltage shut-down.

Calibration

We tested ANM performance three ways: preliminary testing in the laboratory (Barber et al. 1995), calibration and re-adjustment at the end of each field season, and field deployment of ANMs in pairs. Barber et al. (1995) tested three prototype instruments before the start of the 1995 field season and found that A- and C-weighted frequency responses were sensitive to case rigidity. Initially, A-weighted frequency response was close to ANSI standards (ANSI S1.4-1983) in the range from 125 to 2000 hertz (Hz), but deviated outside allowable tolerances above and below. After stiffening the case, performance improved. C-weighted frequency responses were even farther from standards and deviated from expectation over much of the range, particularly above 1500 Hz. Because of this deviation and the greater effect of wind on C-weighted measurements, we decided not to use C-weighting during the field study.

Barber et al. (1995) found that the dynamic range of the instruments was excellent between 60 and 110 dBA, deviating by no more than 1.5 dB. Threshold performance tests showed that the hardware threshold deviated by no more than 2.5 dB from the expected level; other thresholds were not examined. However, during actual measurements made by the instrument, event duration sometimes differed from expected by 50%, single event maximum sound level (L_{max}) by up to 10 dB, and A-weighted sound exposure level (ASEL) by up to 7 dB. No further work was done on the ANMs prior to their deployment in our study.

The ANMs also were calibrated in an ISO-rated sound isolation chamber at the Armstrong Laboratories, Wright-Patterson Air Force Base (AL/OEBN) in 1996 (before the field season), 1997 (before the field season), and in 1999 (at project completion). During these calibrations, ANMs were exposed to white-

noise bursts of known spectrum, duration, and level in the ISO chamber. A- and C-weighted sound exposure level (SEL) and the sampling threshold were measured for each instrument (Appendix 3-1).

ANM Deployment and Recovery

During the three years of this study, 127 ANMs were deployed successfully near active Peregrine Falcon nests; 38 in 1995, 42 in 1996, and 47 in 1997. Most nests were in areas used by the USAF for low-level training missions in MOAs and MTRs. However, some ANMs (10 in 1995, 7 in 1996 and 1997) were placed near nests expected to have little or no aircraft activity.

Once a nest site was determined to be occupied or active (i.e., at least one member of pair defending ledge, or adult in incubating posture), a nearby location on the cliff was selected for ANM deployment. Although we placed ANMs as close as possible to the active nest (~50 m), we took special care to minimize disturbance of nesting birds. In most cases, we were successful at deploying the monitors without dislodging the incubating bird.

We placed ANMs on a flat, or nearly flat, surface, mimicking as closely as possible the physical characteristics of the nest ledge (e.g., slight overhang, wooded side slope, similar elevation and exposure). Because several ANMs were damaged by precipitation in 1995, we usually placed the ANMs under broad, protected ledges in 1996 and 1997. A 12-inch metal stake was driven into the slope directly beneath the ANM, which was fastened to the exposed head of the stake with a small locking carabiner. If we did not feel that the attachment was secure enough, the ANM was secured with heavy gauge wire to adjacent rocks or additional stakes. After the ANMs were secured, they were initialized and tested. The location of each ANM was described in a field notebook, noted on a photograph along with the nest location, and the site was discretely flagged to facilitate relocation.

When retrieving the ANMs, we approached the cliff carefully to determine current status and activity of Peregrine Falcons. We then retrieved the ANMs and terminated data collection by inserting the suspend plug into the unit. We recorded the time of recovery, visually inspected the condition of the ANM, and determined whether it appeared to be working (i.e., still had battery charge) at the time of pickup.

During each year of the study, pairs of ANMs were deployed at selected peregrine nests on the Tanana River to estimate measurement error and as a back-up measure, in the event of failure of one of the instruments at these especially important sites (i.e., those selected for behavioral monitoring). Paired ANMs were separated by a small distance (<5 m), and we made every effort to insure comparable cover,

slope, and aspect at both sites. Because many of the ANM pairs were placed near behavioral observers, we were able to compare observational data of some actual overflights (aircraft type, altitude, slant distance) with ANM records.

Data Screening and Summarization

We downloaded the ANMs and screened the data to eliminate records that did not represent aircraft overflights. We eliminated the following records:

- events <2 sec duration (such events were too short to be produced by aircraft);
- data collected after retrieval time;
- all weekend records (military training usually did not occur on weekends) and;
- all events with A-weighted Sound Exposure Level (ASEL) > C-weighted Sound Exposure Level (CSEL)/(in order to reduce false positive records due to wind).

We also reviewed the time history of the ANM records to eliminate events that could not reasonably result from military overflights. For example, a sequence of events triggered immediately before retrieval was likely to be the result of our approach to collect the device. In 1995, we retained 268 of 656 events (41%) after screening. In 1996 and 1997, we retained 591 of 787 events (71%) and 1,353 of 1,431 events (95%), respectively. The proportions of events retained in 1996 and 1997 were higher because (1) the ANMs were in much better condition mechanically, (2) methods for deploying the ANMs had improved, and (3) more overflights occurred in those years.

From this screened data set, we calculated the following summary statistics for each deployment:

1. Total Number of Events

- 2. Logarithmic Mean Single Event Maximum Sound Level (L_{max})-**The log average of all the single event maximum sound levels (12.5 ms integration time, A-weighted). This average was a rough measure of the typical peak levels detected at each site. It was calculated by

$$MEAN L_{MAX} = 10 * \log_{10} \{ 1/n * \sum (10^{(L_{max}/10)}) \} \quad (1)$$

where n = number of events recorded

- 3. Logarithmic Mean A-Weighted Sound Exposure Level (ASEL)-**The log average of all the single event sound exposure level (A-weighted). This measure was the average sound energy of all events at each site. It was calculated as follows:

$$\text{MEAN ASEL} = 10 \cdot \log_{10} \{ 1/n \cdot \sum (10^{(\text{ASEL}/10)}) \} \quad (2)$$

where n = number of events

4. Mean Event Duration

5. **Daily Average A-Weighted Sound Exposure Level (ASEL)**-Because the ANMs did not accurately measure background noise levels, it was not possible to calculate a standard measure of average sound level, such as L_{eq} (equivalent-continuous sound level). Some such measure was needed, however, to compare relative exposures between nests over the entire monitoring period. Fortunately, noisy events such as aircraft overflights have a disproportionate effect on daily averages. The measure we selected to represent typical exposure was the Daily Average ASEL. We computed it by summing the A-weighted sound exposures of all events detected at the site, dividing by the number of days monitored, and calculating a level from the result. Note that this measure is not reliable when no events are detected. In that case, the value was given at 60 dB (roughly, the noise floor of the ANM). The calculation was performed as follows:

$$\text{DAILY AVERAGE ASEL (dB)} = 10 \cdot \log \{ 1/d \cdot \sum (10^{(\text{ASEL}/10)}) \} \quad (3)$$

where ASEL = the average ASEL of paired noise events and ASEL of non-paired noise events, and

d = the number of weekdays the ANM was deployed.

We eliminated weekends from the Daily Average ASEL because overflights on Saturdays and Sundays were rare, making it unlikely that any events would be detected on those days. The daily average A-weighted sound exposure level is best interpreted as a measure of aircraft noise on days when Peregrine Falcons were likely to be exposed, rather than an average over all days of deployment.

RESULTS

ANM Performance

The ANMs proved to be vulnerable to water damage, power-supply failure, and malfunction of the A- and C-weighting networks. Sampling thresholds also tended to drift from the pre-set, calibrated levels. Of 44 ANMs available in 1995, 6 had a failure of one or both of the weighting networks, and 7 had thresholds >5 dB from the expected level. Only 38 of the 44 ANMs eventually were deployed. During calibration tests in 1996, only one ANM deviated from expected in its measurement of white-noise levels (-9.5 dB),

but 15 of 48 ANMs were found to have thresholds significantly out of calibration (>5 dB difference); 1 ANM differed by >10 dB. Forty-two monitors were deployed in 1996.

Even more deviations were found during the 1999 calibration tests. Of 47 ANMs retrieved at the end of the 1997 season and calibrated in 1999, 6 had bad A- or C-weighting networks and white-noise measurements differed from expected by >10 dB. The remaining ANMs were within 5 dB of expected. Thresholds of most ANMs had drifted from their pre-set level; 14 were off by 10 dB and more than 30 were off by 5 dB or more.

An examination of the data for all instruments (Appendix 3-2) showed trends in the thresholds and number of events recorded each year. First, the modal threshold drifted upward, from 75-80 dBA in 1996 to 80-85 dBA in 1997 to 85-90 dBA in 1999 (Figure 3.3a), although the instruments were readjusted each year to bring them back to desired settings (calibration sampling threshold = 80 dBA, A-weighted noise level = 85.5 dBA, C-weighted noise level = 94 dBC). Because the instruments were never field-calibrated and because a long lag always occurred between deployment and calibration, some of this drift may have occurred after retrieval. In all likelihood, however, the instrument thresholds drifted from pre-set thresholds to an unknown degree during deployment.

The number of events attributed to aircraft increased substantially in 1997. This recorded increase was not a result of an increase in the modal number of events per instrument deployed, which remained between 1-20 events in all three years (Figure 3.3b), but rather was the result of better deployment methods and increasing USAF activity in support of the project. The increase in number of events attributed to aircraft seemed to compensate for any upward shift in thresholds, which would have tended to reduce the number of events detected.

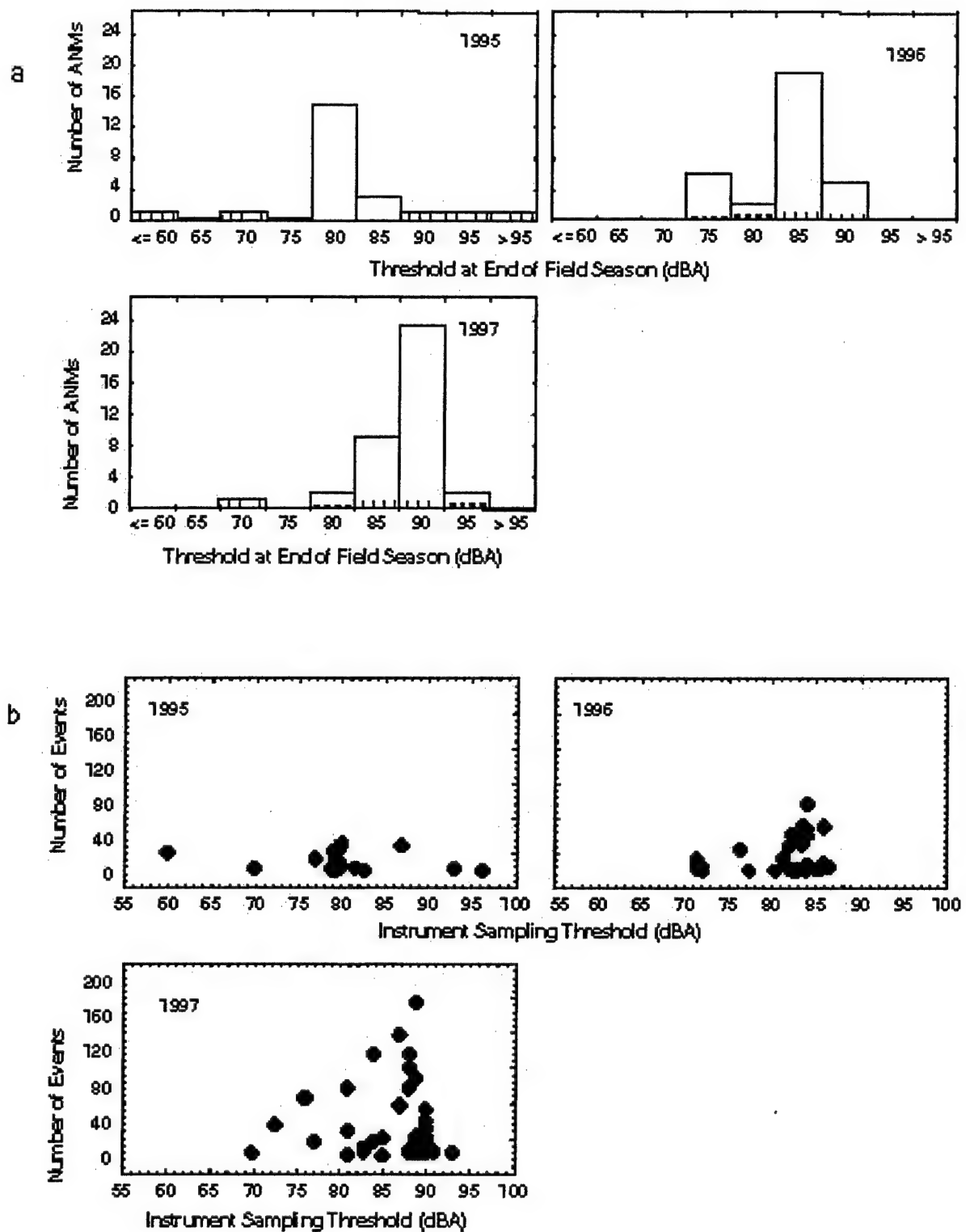


Figure 3.3 *Changes in Animal Noise Monitor (ANM) thresholds (A) and event counts (B) over the three years of the study at Peregrine Falcon nest sites in east-central Alaska, 1995-1997.*

Noise Measurements at Peregrine Falcon Nests

1995 - We deployed a total of 38 monitors at 33 peregrine nests; 5 sites on the Tanana River had paired monitors. We were able to retrieve data from 33 units, whereas 5 units failed, including 1 paired monitor.

Failures of ANMs in all but one instance were due to moisture inside the case. Additionally, eight monitors stopped recording at various times during deployment, but all could be downloaded. Overall, the monitors were deployed for 42,448 hours and collected data over 30,247 hours or for 80.1% of the time deployed (Table 3.3). During that time, 656 noise events were recorded. Screening these data resulted in a total of 268 valid overflight events (Kugler 1996).

Table 3.3. *Deployment and overflight information by year and drainage for Animal Noise Monitors (ANMs) deployed to record noise events at Peregrine Falcon nest sites in areas in east-central Alaska used by the U.S. Air Force for military training, 1995-1997.*

Year	Drainage	Nests	Days Deployed	Hours of Monitoring	% Time Active	Number of Events	Mean Number of Overflights / Day
1995	Fortymile	3	149	1,225	34.2	4	0.04
	Seventymile	5	253	5,846	96.2	4	0.02
	Birch	7	368	4,622	52.4	61	0.48
	Goodpaster	1	52	372	29.8	4	0.36
	Kandik	1	48	516	44.4	5	0.31
	Nation	1	50	1,205	100.0	0	0.00
	Salcha	4	176	1,127	26.7	71	2.51
	Tanana	11	688	15,334	92.8	119	0.26
	Subtotal	33	1,785	30,247	80.1	268	0.52
1996	Fortymile	5	215	5,157	100.0	5	0.03
	Seventymile	4	173	3,241	78.2	4	0.03
	Birch	8	387	9,279	100.0	199	0.71
	Goodpaster	1	45	1,080	100.0	4	0.13
	Salcha	4	184	4,407	100.0	124	0.94
	Tanana	12	898	21,542	100.0	255	0.42
	Subtotal	34	1,901	44,706	98.0	591	0.44
1997	Fortymile	6	273	6,038	92.0	36	0.20
	Seventymile	4	185	4,093	92.2	7	0.06
	Birch	10	476	9,368	81.9	161	0.53
	Goodpaster	3	138	3,042	91.9	236	2.39
	Salcha	4	199	4,357	91.5	356	2.65
	Tanana	12	1,090	24,500	93.6	557	0.77
	Subtotal	39	2,361	51,398	90.7	1,353	0.86
Total		106	6,047	126,351	87.1	2,212	0.62

The ANMs recorded from 0-31 events (Appendix 3-2). The average ASEL recorded was 98.2 dB, with a range of 84 to 113 dB (Table 3.4). Average event duration was 6.1 sec with a range of 2.1 to 30.8 sec. The mean daily average ASEL was 83.2 dB and ranged between 60 and 114.5 dB. Sound levels reported by paired ANMs had good correspondence, with the mean difference in ASEL of "paired" events (a single event detected simultaneously by each monitor) varying from 0.2-1.7 dB, with a standard deviation of 0.7-1.1 dB (Table 3.5). Percentage of events detected by both units ranged from 46% to 75%.

Table 3.4. Descriptive statistics by year and drainage for noise events recorded by Animal Noise Monitors (ANMs) at Peregrine Falcon nest sites overflowed by U.S. Air Force jets, east-central Alaska, 1995-1997.

Year	Drainage	L _{max} ¹ (dB)			ASEL ² (dB)			Duration (sec)			Daily Avg. ASEL (dB)		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1995	Fortymile	96.5	99.9	102.5	87.5	96.6	101.0	2.1	2.4	17.1	60.0 ³	69.3	88.0
	Seventymile	94.0	103.7	106.5	90.5	94.8	97.0	2.4	2.3	12.4	60.0	74.8	90.4
	Birch	88.5	103.2	117.0	84.0	98.4	109.0	2.3	6.4	28.8	60.0	82.3	98.9
	Goodpaster	88.5	98.7	101.0	84.5	96.8	99.5	2.1	6.7	13.6	88.2	88.2	88.2
	Kandik	83.5	84.9	86.5	87.0	93.0	95.5	3.4	16.5	27.6	85.4	85.4	85.4
	Mission	105.0	105.0	105.0	105.0	105.0	105.0	4.6	4.6	4.6	60.0	60.0	60.0
	Salcha	87.0	104.0	119.0	85.5	100.9	113.0	2.1	8.9	30.8	60.0	90.9	105.1
	Tanana	88.5	99.7	114.0	86.0	97.8	112.5	2.1	7.1	24.5	60.0	89.9	114.5
	Subtotal	83.5	101.1	119.0	84.0	98.2	113.0	2.1	6.1	30.8	60.0	83.2	114.5
1996	Fortymile	87.0	100.3	110.0	85.5	91.1	96.0	2.1	2.3	5.5	60.0	70.7	84.1
	Seventymile	95.5	104.6	110.0	83.5	93.2	101.0	2.4	1.4	3.8	60.0	70.3	86.7
	Birch	85.0	101.5	122.0	82.0	97.0	116.0	2.1	7.0	25.9	70.4	92.9	105.2
	Goodpaster	94.5	109.2	115.0	90.0	105.7	111.5	3.0	9.2	20.3	96.7	96.7	96.7
	Salcha	84.5	105.9	120.5	82.5	100.7	111.5	2.1	7.5	29.1	95.9	99.7	103.0
	Tanana	85.5	103.2	120.0	85.0	100.3	115.5	2.1	4.9	30	60.0	87.2	100.5
	Subtotal	84.5	103.1	122.0	82.0	98.0	116.0	2.1	5.0	30	60.0	85.9	105.2
1997	Fortymile	83.5	96.1	113.0	78.5	94.4	109.0	2.1	7.4	31.6	60.0	82.7	96.8
	Seventymile	87.0	98.1	110.0	85.5	88.3	94.0	2.1	3.5	8.8	70.7	74.9	79.9
	Birch	84.0	102.5	121.5	80.0	97.6	121.5	2.1	6.1	31.9	60.0	86.6	110.6
	Goodpaster	83.5	103.8	119.0	80.5	100.4	115.5	2.0	9.9	31.9	96.2	102.4	109.6
	Salcha	83.5	104.6	118.5	80.0	100.0	113.5	2.0	9.5	29.2	100.9	103.7	106.4
	Tanana	81.5	98.4	120.0	80.0	94.7	113.0	2.1	7.1	31.9	71.9	92.1	106.3
	Subtotal	81.5	100.1	121.5	78.5	95.6	121.5	2.0	7.0	31.9	60.0	89.4	110.6
Total		81.5	101.3	122.0	78.5	97.1	121.5	2.0	6.1	31.9	60.0	86.3	114.5

¹ L_{max} = single event maximum sound level

² ASEL = A-weighted sound exposure level

³ Assigned minimum value for nests with no sound events.

Table 3.5. Results of paired Animal Noise Monitors (ANM) measurements at Peregrine Falcon nest sites in east-central Alaska, 1995.

	Nest Number				
	205	211	221	280.5	288.5
ANM Pair	S007/S040	S001/S035	S033/S049	S034/S043	S030/S032
Threshold Deviation	7.0/-0.1	1.3/9.1	-0.3/-1.0	-0.7/-0.9	-/0.1
Days in Operation	39	39	39	56	56
Total Recorded Events	27	20	24	16	20
Events Detected by Both ANMs	20	15	11	-	14
Events Detected by One ANM Only	7	5	13	16	6
Events Detected by Both ANM (%)	74	75	46	-	70
Average Difference	1.5	0.9	0.2	-	1.7
Between ANMs (ASEL ¹)					
SD of Difference	0.9	0.7	1.0	-	1.1
Between ANMs (ASEL)					

¹ A-weighted sound exposure level

The number of overflights detected simultaneously by observers and ANMs varied greatly from site to site (Table 3.6). From 67% to 93% of the observed events considered sufficiently close (within 500 ft) triggered the ANMs. A additional 22 events were considered too distant to disturb Peregrine Falcons and did not trigger the instruments. These results suggested that ANMs detected close approaches with high probability.

1996 - In 1996, we were able to increase the number of ANMs deployed, placing 42 monitors at 34 peregrine nests; 8 sites on the Tanana River had paired monitors. During this year, only two monitors (including one of a pair) failed completely and yielded no data. Total monitoring time was 44,706 hours, an increase of 47.8% from 1995 (Table 3.3). All but one of the functioning monitors was active during the entire deployment period. During this time, the monitors recorded 787 noise events, which screening reduced to 591 events (Kugler 1997a). This increase in the number of valid overflight events from the number in 1995 was due to the reduced failure rate of the ANMs and did not represent an increase of overflight activity. The mean number of overflights per day was less in 1996 than in 1995 (Table 3.3).

The number of aircraft overflights detected per nest in 1996 ranged from 0-75, with an average ASEL of 98 dB (range 82.0-116 dB; Table 3.4). The mean daily average ASEL was 85.9 dB and ranged from 60-105.2 dB. The average event duration was 5 sec and varied from 2.1-30 sec (Table 3.4).

Analysis of the paired overflight events again indicated good correspondence between monitors, although variability was greater in 1996 than in 1995 (paired events detected ranged from 11-85% of total events).

The average deviation in ASEL values was 0 to 0.9 dB, with a standard deviation of 0.6 to 2.7 dB (Table 3.7).

Table 3.6. Results of observer records compared with paired Animal Noise Monitor (ANM) measurements at Peregrine Falcon nest sites in east-central Alaska, 1995.

	Nest Number				
	205	211	221	280.5	288.5
ANM Pair	S007/S040	S001/S035	S033/S049	S034/S043	S030/S032
Threshold Deviation	7.0/-0.1	1.3/9.1	-0.3/-1.0	-0.7/-0.9	-/0.1
Days in Operation	39	39	39	56	56
Total Military Jet Overflights	27	0	26	3	11
Observed					
Total Observed Overflights	25	0	21	2	0
Measured by ANMs					
Total Observed Overflights	93	0	81	67	0
Measured by ANMs (%)					
Observed Events Detected by Both ANMs (Events Observed)	20 (20)	0 (15)	9 (11)	-	7 (14)
Events Detected by One ANM Only (Events Observed)	5 (7)	0 (5)	12 (13)	2 (16)	0 (6)

Table 3.7. Results of paired Animal Noise Monitors (ANM) measurements at Peregrine Falcon nest sites in east-central Alaska, 1996.

	Nest Number					
	280.5	288.5	427	431	438.5	443
ANM Pair	S009/S043	S037/S046	S001/S040	S013/S032	S004/S026	S021/S050
Threshold Deviation	2.0/2.5	-6.5/-8.5	3.5/-9.5	7.0/4.0	3.0/3.5	1.5/-10.0
Days in Operation	72	72	71	93	82	34
Total Recorded Events	27	41	53	44	30	14
Events Detected by Both ANMs	3	35	29	16	24	9
Events Detected by One ANM Only	24	6	24	28	6	5
Events Detected by Both ANM (%)	11	85	55	36	80	64
Average Difference Between ANMs (ASEL ¹)	0.2	0.9	0.1	0.0	0.1	0.9
SD of Difference Between ANMs (ASEL)	1.0	2.7	1.0	0.6	0.7	1.0

¹ A-weighted sound exposure level

Results from units detecting the fewest number of paired events (11%; S009/S043 at nest 280.5) were instructive. The two ANMs differed little in threshold (0.5 dB) and ASEL values (0.2 dB; SD = 1.0 dB), yet one instrument (S043; threshold 0.5 dB higher) detected only 2 of the 24 unpaired events. Why was such a high proportion of events missed when the threshold difference was so small? Many events detected by these instruments were very short (<5 sec; mean 5.9 sec [S009] and 7.6 sec [S043]). Only 1 of 57 overflights reported by observers was detected by the instruments (Table 3.8), which is suggestive of low-intensity overflights. The instrument that detected shorter events (S009) also was the one that detected more events. Either the hardware or duration threshold (not calibrated) could have been at fault.

1997 - In 1997, we deployed 47 ANMs at 39 Peregrine Falcon nests (Table 3.3); 8 sites along the Tanana River again had paired monitors. Three monitors (including 2 paired monitors) failed completely and yielded no data. Total monitoring time increased to 51,398 hours in 1997, but only 6 of the monitors were functional during the entire deployment period. The remaining 38 monitors were active 40-99% of the period.

ANMs in 1997 recorded a total of 1,431 noise events, which was reduced to 1,353 valid overflight events after screening (Kugler 1997b). This was a substantial increase in overflights over the two previous

years. This increase was the result of longer deployment time, a greater number of units deployed, and an increase in USAF overflights (Table 3.3).

The number of overflights per nest ranged from 0 to 175. The average ASEL for all overflights was 95.6 dB, with a range of 78.5-121.5 dB (Table 3.4). The average event duration was 7 sec (range of 2-31.9 sec). The mean daily average ASEL was 89.4 dB and varied between 60 to 110.6 dB.

Paired monitors detected between 33 and 73% of the total number of events. The average difference between monitors ranged from 0.1-4.2 dB, with a standard deviation of 1.2-4.1 dB (Table 3.9). Two of the pairs differed by >3 dB. Although three of the instruments were found to be out of calibration when tested in 1999 (A- and C- weighted values differing substantially from expectation; Appendix 3-1), those instruments were not responsible for the large discrepancies. In one case (nest site 221.5; S001/S002; deviation 4.2 dB), thresholds differed by only 1 dB, while in the other (nest site 436; S016/S017; deviation 3.1 dB), thresholds differed by 3 dB. As discussed above, the deviation in pair S016/S017 could easily have resulted from the threshold difference. For pair S001/S002, all missed events (i.e., events detected by one ANM only) were <6.5 sec in duration, whereas paired events ranged up to 19.4 sec. Substantial differences occurred in durations recorded by the pair for the same events, 2.4 vs. 19.4 sec in one case.

Table 3.8. Results of observer records compared with paired Animal Noise Monitors (ANM) measurements at Peregrine Falcon nest sites in east-central Alaska, 1996.

	Nest Number					
	280.5	288.5	427	431	438.5	443
ANM Pair	S009/ S043	S037/ S046	S001/ S040	S013/ S032	S004/ S026	S021/ S050
Threshold Deviation	2.0/2.5	-6.5/-8.5	3.5/-9.5	7.0/4.0	3.0/3.5	1.5/-10.0
Days in Operation	72	72	71	93	82	34
Total Military Jet Overflights Observed	57	78	155	96	134	146
Total Observed Overflights Measured by ANMs	1	13	1	2	4	2
Total Observed Overflights Measured by ANMs (%)	2	17	0.6	2	3	1
Observed Events Detected by Both ANMs (Events Observed)	1 (3)	13 (35)	1 (29)	2 (16)	3 (24)	2 (9)
Events Detected by One ANM Only (Events Observed)	0 (24)	0 (6)	0 (24)	0 (28)	1 (6)	0 (5)

Table 3.9. Results of paired Animal Noise Monitors (ANMs) measurements at Peregrine Falcon nest sites in east-central Alaska, 1997. ANMs that were found to make large measurement errors when calibrated in 1999 are underlined.

	Nest Location				
	221.5	280.5	427	436	438.5
ANM Pair	S001/ S002	<u>S006/</u> <u>S007</u>	S011/ <u>S013</u>	S016/ S017	S018/ <u>S020</u>
Threshold Deviation	4.0/3.0	10.0/5.0	9.0/7.0	7.0/10.0	1.0/5.0
Days in Operation	73	72	72	72	36
Total Recorded Events	15	30	88	138	55
Events Detected by Both ANMs	5	22	36	64	20
Events Detected by One ANM only	10	8	52	74	35
Events Detected by Both ANM (%)	33	73	41	46	36
Average Difference Between ANMs (ASEL ¹)	4.2	0.1	0.7	3.1	1.0
SD of Difference Between ANMs (ASEL)	4.1	1.8	2.3	2.0	1.2

¹ A-weighted sound exposure level

Paired ANM Measurements

In 1995, five nest locations were instrumented with two ANMs (Table 3.5). Data from ANM S043 were unusable due to an error in the clock settings; therefore, data from only four pairs were available for comparison. Between 46 and 75% of the total number of events were detected by both ANMs. In other words, one or the other of the instruments failed to trigger during 25 to 54% of the overflights.

Differences in thresholds between paired monitors seemed to be the most likely explanation for the missed events. Based on calibrated (sampling) thresholds, however, the ANM data did not clearly support this hypothesis. ANM pairs with the greatest differences in threshold often detected the highest percentage of the same events. For example, in 1995, ANM pairs at nests 205 and 211 detected 74 and 75% of all events, respectively (Table 3.5), even though post-season calibration showed that their thresholds differed from the expected level by 7.1 and 7.8 dB, respectively. In contrast, the ANM pair at nest 221 differed in calibrated level by less than 1 dB, but only 46% of events were detected by both monitors.

To understand such contradictions, we examined the duration of events and noise metrics for paired ANMs. A good example was ANM pair S016/S017 situated at nest 436 in 1997 (Table 3.9 and Figure 3.4). These ANMs combined detected the highest total number of events (64) of any paired deployment, but overlapped poorly (only 46% of these events were detected by both instruments). Although the distributions overlapped sufficiently that mean duration, L_{max} , and ASEL for each instrument differed little (2 sec in duration and 3 dB in level), S016 nevertheless reported longer events at higher levels (Figure 3.4). The differences were significant (one-way ANOVA, $df_{1,126}$, $n = 64$, $p < 0.05$). The difference in level was close to the difference in threshold between the two instruments (S017 had a threshold 3 dB higher than S016). At nest site 436, many of the events were short and low in amplitude. Under such conditions, differences in threshold obviously had a marked effect on the number of events detected, although levels differed little.

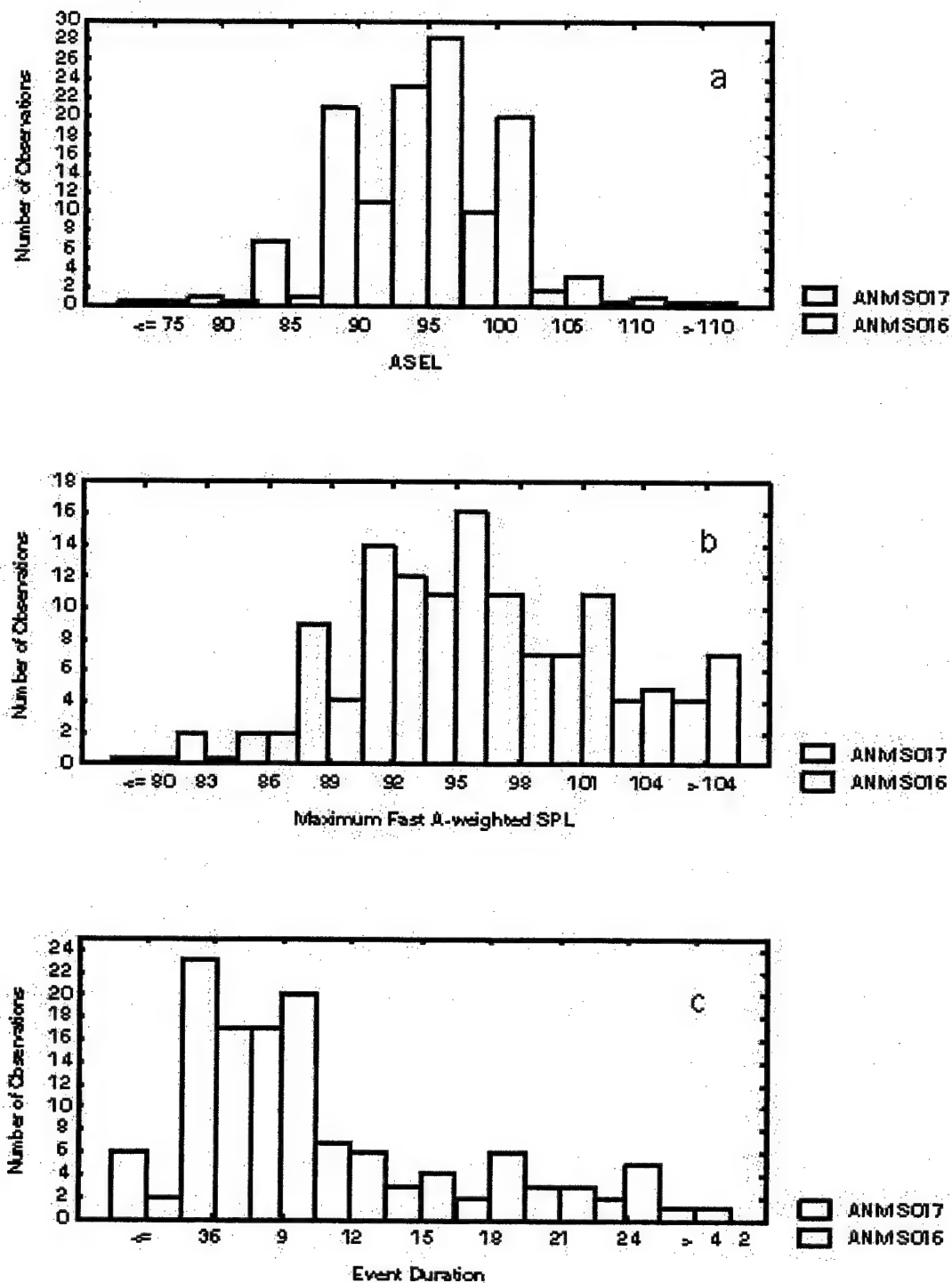


Figure 3.4. Comparison of (A) mean A-weighted sound exposure level (ASEL) (db); (B) single event maximum sound level (L_{max})(db); and (C) event duration (sec) recorded by two Animal Noise Monitors (ANM S017 and S016) at a Peregrine Falcon nest site in east-central Alaska, 1997

Calibrated real-time recordings never were collected simultaneously with paired ANM measurements, so it is impossible to determine exactly what contributed to the differences in events detected. However, after examining all the paired data, it became clear that the pattern found in pair S016/S017 was consistent throughout the data. When both units collected events, the maximum sound levels and sound exposure levels were similar, but if many short, low amplitude events occurred, differences in duration or level thresholds, even minor ones, appeared to have a large effect on event counts and durations. In some cases, one instrument captured virtually all of the missed events (those detected by only one instrument) and durations showed correspondingly large differences. In others, the instrument with the higher threshold missed more events. Large deviations in the A- and C-weighting networks may have contributed to the problem in undetectable ways, but could not be associated directly.

DISCUSSION

During the three-year period 1995-1997, we deployed 127 ANMs at 106 Peregrine Falcon nests. The monitors recorded 2,212 aircraft overflights during 126,351 hours (>5,264 days) of monitoring. The ANMs allowed us to monitor considerably more nests and over a longer period than would have been possible for human observers. In addition, they allowed us to collect noise data close to nest sites over long periods without disturbing the birds. In this regard, the ANMs were successful.

The failure rate of ANMs and persistent tendency to go out of calibration were problems throughout the study, however. Only in 1996 did we have near-complete success with the ANMs. In 1995, many units failed when moisture from rain seeped through the seals on the instrument case. We eliminated seepage thereafter by placing monitors under slight overhangs to prevent direct contact with rain. How well the instrument would perform on a radio-collar is unclear; an ANM on a collar inevitably would be exposed to rain, but the animal rarely would sit still long enough for water to pool. We were unable to ascertain the cause of the failures of instruments during the third year. Water seepage was not a problem and most of the instruments functioned when calibrated in 1999.

A few instruments were tested extensively prior to ANM development (Barber et al. 1995). All the instruments used in the field were calibrated after each field season. We also estimated instrument error during the season by placing pairs of ANMs side by side at selected nest sites during the breeding season. Calibration measurements indicated that the instrument sampling threshold drifted upward during the study, from 75-80 dBA in 1995 to 85-90 dBA in 1999 (1997 field season), despite the ANMs being recalibrated and adjusted before the start of each field season. The reasons for this drift were not identified. The instruments are designed to be inexpensive and to be left unattended for many months under rigorous field conditions. Inevitably, these design elements make them more difficult to keep in

calibration. To insure the best possible results, future ANMs should be equipped with some type of internal calibration electronics.

Fortunately, the daily average ASEL, which is used to compare relative exposures between nests during the field season, was uncorrelated with drift in thresholds. The drift may or may not have had a consistent effect on the number of events detected; the change was impossible to differentiate from improvements in deployment and increasing aircraft activity in support of the field study. Modal number of events was small (1-20 events/season) and constant across all three field seasons. In 1997, an increase in aircraft activity and ANM coverage resulted in sites with much higher event counts (>150 events/season), despite ANM thresholds 10 dB higher after the field season in 1997, than in 1995. The most likely explanation for this counterintuitive result is that changes in thresholds from the beginning of the season (when the instrument was in good calibration) to end (when it was not) were occurring at unpredictable intervals.

Using (log) average ASEL as a metric, the analysis of event data from the paired monitors deployed on the Tanana River generally showed good correspondence between events recorded by both monitors. Averaged over all the events detected by both instruments, differences were typically <1 dB and never greater than 4.2 dB. However, many paired instruments did not detect a high proportion of events simultaneously, despite their being placed close together. While propagation issues may have explained some of the differences, we believe that the best explanation is small differences between instruments in thresholds (controlling both level and duration). Because only 1 of the 5 thresholds (the sampling threshold) was examined during calibration, drift in the others would not have been detected. Such variation certainly was suggested by measurements during instrument testing at the beginning of the project (Barber et al. 1995). When we examined the non-paired events (events detected by one but not both instruments), we found differences in event duration of up to an order of magnitude (in the worst case 2 vs. 19 sec). Clearly instruments were poorly matched in the thresholds controlling event onset and offset. As the instruments aged, this mismatch increased. Less than 50% of total events were detected by both instruments in 1 of 4 cases in 1995, 2 of 6 in 1996, and 4 of 5 in 1997.

In summary, the ANMs allowed us to efficiently collect detailed noise exposure information at a large sample of Peregrine Falcon nest sites. Even with their obvious deficiencies in accuracy and precision of data collection, the ANMs were a powerful tool. However, if such instruments are to be designed and built in the future, their field-worthiness must be a much higher priority. They must be field-hardened to resist water seepage, rough handling, and temperature variations, and they must be equipped with internal calibration electronics to allow data to be corrected after the inevitable changes in instrument performance after months of exposure in the field. Every effort should be made to collect real-time recordings

simultaneously with at least some ANM event records to determine how well they perform under actual field conditions, particularly as they age.

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Dr. Dan Roby (OSU) served as Principal Investigator for this project, and Captain Mike Carter, USAF AL/OEBN, was the Air Force contract manager.

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Michael Patterson at AL/OEBN (Wright-Patterson AFB) calibrated the ANMs in 1996, 1997, and 1999.

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Table 3.10. *Results of observer records compared with paired Animal Noise Monitors (ANMs) measurements at Peregrine Falcon nest sites in east-central Alaska, 1997. ANMs that were found to make large measurement errors when calibrated in 1999 are underlined.*

	Nest Location				
	221.5	280.5	427	436	438.5
ANM Pair	S001/S002	S006/S007	S011/S013	S016/S017	S018/S020
Threshold Deviation	4.0/3.0	10.0/5.0	9.0/7.0	7.0/10.0	1.0/5.0
Days in Operation	73	72	72	72	36
Total Military Jet	7	50	49	42	6
Overflights Observed					
Total Observed Overflights	3	22	3	22	0
Measured by ANMs					
Total Observed Overflights	43	44	6	52	0
Measured by ANMs (%)					
Observed Events Detected	1 (5)	19 (22)	3 (36)	8 (64)	0 (20)
by Both ANMs (Events					
Observed)					
Events Detected by One	2 (10)	2 (8)	0 (52)	14 (74)	0 (35)
ANM Only					
(Events Observed)					

Appendix 3-1. A- and C-weighted sound pressure levels and thresholds of the Animal Noise Monitors (ANM) during calibrations in 1996, 1997, and 1999. Stippled cells differ from expectation by >5 dB. Shaded cells differ by ≥10 dB.

Expected	1996				1997				1999			
	dBA	dBA dBC	dBA dBC	Thresh	dBA	dBA dBC	dBA dBC	Thresh	dBA	dBA dBC	dBA dBC	Thresh
Serial												
C001	86.5	1.0		81.3	85.5	0.0		71.5	85.5	0.0		90.0
C002	86.5	1.0		81.0	85.5	0.0		72.0	85.0	-0.5		89.0
C003	86.5	1.0		86.4	86.0	0.5		86.0	84.5	-1.0		88.0
S001	86.0	0.5		86.0	85.5	0.0		83.5	88.0	3.5		84.0
S002	85.5	0.0	94.0	86.3	85.5	0.0	0.0	84.0	90.5	5.0	4.0	83.0
S003	85.5	0.0	94.0	86.0	84.0	-1.5	-1.5	82.0	88.5	4.0	4.0	85.0
S004	86.0	0.5	94.0	79.9	85.0	-0.5	-0.5	83.0	89.0	3.5	3.0	83.0
S005	85.0	-0.5	93.0	87.0	84.0	-1.5	-1.0	86.0	88.5	13.0	12.0	90.0
S006	85.5	0.0	94.0	70.0	85.5	0.0	-0.5	85.5	87.0	1.5	1.0	85.0
S007	85.5	0.0	94.0	70.0	85.0	-0.5	0.0	83.0	88.0	2.5	2.5	90.0
S008	85.5	0.0	94.0	70.0	85.5	0.0	0.0	82.0	85.5	0.0	-1.0	87.0
S009	85.5	0.0	94.0	79.0	85.5	-0.5	0.0	83.5	84.5	-1.0	-1.0	89.0
S010	85.5	0.0	94.0	79.0	85.5	-0.5	0.0	84.0	88.0	2.5	3.0	89.0
S011	123.0	37.5		80.0	85.5	0.0		87.0	106.0	106.0		90.0
S012	86.0	0.5	94.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S013	86.0	0.5	94.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S014	86.0	0.5	94.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S015	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S016	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S017	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S018	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S019	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S020	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S021	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S022	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S023	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S024	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S025	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S026	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S027	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S028	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S029	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S030	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S031	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S032	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S033	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S034	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S035	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S036	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S037	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S038	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S039	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S040	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S041	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S042	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S043	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S044	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S045	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S046	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S047	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S048	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S049	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S050	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0
S051	86.0	0.5	123.0	80.0	85.5	0.0		85.5	87.0	1.5	1.0	85.0

Appendix 3-2. Noise exposure information recorded by Animal Noise Monitors (ANMs) at Peregrine Falcon nest sites in east-central Alaska, 1995-1997.

Year	ANM	# Overflight Events	L_{max}^1 (dB)	ASEL ² (dB)	Duration (sec)	Daily Avg. ASEL (dB)	Events/ Day	Potential Exposure	Hours Deployed
1995	S001	20	101.7	100.3	6.2	113.3	0.5	28.3	1,325
	S002	0	60.0	60.0	0.0	60.0	0.0	0.0	1,197
	S003	4	98.7	96.8	6.7	88.2	0.4	21.1	1,248
	S004	1	106.5	97.0	3.9	82.4	0.0	1.6	1,184
	S005	0	60.0	60.0	0.0	60.0	0.0	0.0	1,175
	S007	27	102.0	100.2	6.3	114.5	0.7	38.2	1,327
	S008	2	101.0	92.6	7.4	81.0	0.1	3.2	1,198
	S009	1	93.5	89.5	3.0	74.9	0.0	1.4	1,315
	S011	0	60.0	60.0	1.0	60.0	0.0	0.0	1,203
	S012	1	99.0	96.0	13.1	60.0	0.3	14.5	1,181
	S016	14	102.4	98.2	9.9	93.7	0.4	21.9	1,274
	S017	2	111.9	98.9	2.8	60.0	0.7	38.7	1,240
	S018	5	84.9	93.0	9.5	85.4	0.3	18.1	1,163
	S021	11	101.5	100.0	8.2	95.8	0.3	16.8	1,254
	S022	22	106.9	100.2	7.7	98.9	0.6	33.6	1,246
	S023	0	60.0	60.0	0.0	60.0	0.0	0.0	1,339
	S025	0	60.0	60.0	0.0	60.0	0.0	0.0	1,241
	S026	2	93.9	94.5	5.5	82.5	0.0	2.8	1,319
	S027	27	104.0	101.7	9.6	101.3	6.8	391.5	1,011
	S028	1	102.0	103.0	24.5	88.0	0.0	1.4	1,318
	S030	20	104.1	100.9	6.7	98.6	0.4	20.4	1,918
	S033	24	101.2	98.1	5.6	97.3	0.6	34.0	1,314
	S034	16	105.5	103.2	9.0	100.7	0.3	16.3	1,921
	S036	11	97.3	94.6	6.7	83.9	1.4	79.8	1,241
	S037	4	99.9	96.6	5.7	88.0	0.1	6.3	1,200
	S039	0	60.0	60.0	0.0	60.0	0.0	0.0	1,176
	S041	0	60.0	60.0	0.0	60.0	0.0	0.0	1,178
	S044	1	99.5	98.5	6.5	83.9	0.1	3.2	1,272
	S045	6	102.0	100.1	43.1	82.3	0.3	17.4	1,916
	S046	2	91.3	88.6	4.2	77.0	0.0	2.8	1,322
	S047	12	104.4	101.1	8.0	97.3	1.1	63.3	1,012
	S048	1	60.0	60.0	4.6	90.4	0.0	1.6	1,196
	S050	31	108.5	104.8	9.4	105.1	1.9	112.4	1,009
	Subtotal	268	91.0	88.7	6.1	83.2	0.5	30.0	42,832
1996	C001	3	103.9	94.2	4.0	84.1	0.1	5.6	1,005
	C002	3	107.3	96.8	3.0	86.7	0.1	5.6	1,006
	C003	50	99.5	96.3	7.4	98.2	1.6	90.6	1,050
	S001	53	103.3	99.9	6.6	98.9	0.7	43.3	2,383
	S002	47	108.7	103.4	8.0	105.2	1.4	80.2	1,133
	S006	8	110.0	102.3	4.3	95.9	0.2	13.3	1,154
	S007	1	87.0	85.5	3.3	70.6	0.0	1.9	1,033
	S008	0	60.0	60.0	0.0	60.0	0.0	0.0	1,110

Year	ANM	# Overflight Events	L_{max}^1 (dB)	ASEL ² (dB)	Duration (sec)	Daily Avg. ASEL (dB)	Events/ Day	Potential Exposure	Hours Deployed
1996 (cont.)	S009	27	100.8	99.8	5.9	95.1	0.4	21.8	2,380
	S010	32	105.3	101.6	9.1	101.6	1.0	58.0	1,055
	S014	2	87.8	83.0	2.7	70.4	0.0	0.4	1,195
	S015	7	101.5	96.3	5.9	89.2	0.2	11.3	1,193
	S020	41	99.8	96.8	7.9	97.8	1.2	69.9	1,134
	S021	14	102.4	97.4	5.4	100.5	0.4	23.9	1,122
	S022	41	106.6	102.3	4.1	99.9	0.6	33.0	2,379
	S023	0	60.0	60.0	0.0	60.0	0.0	0.0	1,033
	S024	1	102.0	89.5	2.4	74.6	0.0	1.8	1,039
	S026	30	107.5	105.0	7.8	100.5	0.4	21.2	2,756
	S027	39	107.5	101.2	6.6	101.8	1.1	62.8	1,156
	S029	1	110.0	93.5	4.3	78.7	0.0	1.8	1,048
	S031	4	109.2	105.7	9.2	96.7	0.1	7.3	1,079
	S032	75	207.3	201.0	12.2	98.7	2.4	136.9	2,265
	S033	38	103.7	99.6	7.6	100.1	1.1	63.0	1,154
	S034	0	120.0	120.0	0.0	60.0	0.0	0.0	2,387
	S035	0	60.0	60.0	0.0	60.0	0.0	0.0	1,034
	S036	1	93.5	90.5	11.3	75.2	0.0	1.7	1,145
	S038	24	109.5	105.2	6.0	103.7	0.7	39.8	1,152
	S041	0	60.0	60.0	0.0	60.0	0.0	0.0	1,030
	S042	0	60.0	60.0	0.0	60.0	0.0	0.0	1,062
	S046	13	104.1	100.3	8.6	92.9	0.2	10.5	2,372
	S048	2	97.0	96.8	8.2	81.2	0.0	1.6	2,379
	S049	34	108.6	102.8	9.2	103.0	1.0	56.3	1,048
	Subtotal	591	94.2	90.2	5.0	85.9	0.4	25.5	45,615
1997	C001	11	94.1	89.5	5.6	81.4	0.2	9.1	2,322
	C002	7	93.2	89.2	7.0	79.0	0.1	5.6	2,378
	S001	15	106.3	101.2	6.7	95.1	0.2	12.8	2,373
	S004	5	91.2	86.5	5.0	71.9	0.1	4.3	2,355
	S006	30	107.0	102.0	5.4	98.9	0.5	26.4	2,355
	S009	56	101.3	98.0	8.0	96.8	0.9	52.4	2,366
	S010	15	95.3	92.2	6.1	85.8	0.3	14.5	2,180
	S011	88	98.9	95.8	9.3	99.5	1.3	77.3	2,351
	S014	116	99.5	96.0	7.5	98.0	1.9	110.3	2,351
	S016	138	98.9	94.8	8.3	100.3	2.1	121.3	2,353
	S018	76	195.5	191.4	16.2	99.2	1.7	98.6	2,169
	S021	22	100.7	100.1	10.0	97.9	0.7	39.9	1,172
	S022	3	94.8	86.9	3.1	76.2	0.1	5.6	1,128
	S024	0	60.0	60.0	0.0	60.0	0.0	0.0	1,125
	S026	0	60.0	60.0	0.0	60.0	0.0	0.0	1,125
	S027	75	103.4	98.0	9.4	100.9	2.2	127.9	1,205
	S028	115	100.7	97.1	10.0	102.1	3.3	190.6	1,184
	S029	100	106.0	102.2	10.3	106.4	3.0	175.8	1,198
	S030	66	108.1	102.7	8.4	105.2	2.1	119.6	1,176
	S031	52	111.8	108.6	10.5	110.6	1.8	104.0	1,082
	S032	15	99.3	96.2	7.8	92.5	0.4	25.6	1,081

Year	ANM	# Overflight Events	L_{max} ¹ (dB)	ASEL ² (dB)	Duration (sec)	Daily Avg. ASEL (dB)	Events/ Day	Potential Exposure	Hours Deployed
1997 (cont.)	S033	29	98.7	95.1	8.3	94.3	1.0	58.0	1,079
	S034	20	97.3	92.5	7.3	90.2	0.6	37.4	1,100
	S035	2	107.9	92.2	2.3	79.9	0.1	4.0	1,113
	S036	1	111.5	100.5	5.3	85.3	0.0	2.1	1,098
	S037	19	106.0	100.9	8.5	98.6	0.6	35.5	1,096
	S038	1	90.0	88.0	4.9	72.7	0.0	1.8	1,106
	S039	3	99.1	87.0	4.7	76.4	0.1	5.4	1,106
	S040	1	95.5	86.0	2.3	70.7	0.0	1.8	1,110
	S041	5	99.7	95.4	6.8	87.2	0.2	10.0	1,108
	S042	0	60.0	60.0	0.0	60.0	0.0	0.0	1,108
	S043	8	94.3	94.5	14.6	88.3	0.3	15.0	1,084
	S045	5	89.6	92.8	6.7	84.6	0.2	10.0	1,093
	S046	14	103.1	100.5	10.8	96.8	0.5	27.1	1,080
	S047	4	93.9	88.6	5.5	79.4	0.1	7.7	1,086
	S048	175	106.1	102.5	12.2	109.6	5.1	298.5	1,103
	S049	21	102.7	98.2	9.4	96.2	0.7	40.6	1,104
	S050	40	102.8	100.6	8.1	101.3	1.3	77.3	1,103
	Subtotal	1,353	97.0	92.9	7.0	89.4	0.9	50.1	56,670
Total		2,212	94.3	90.7	6.1	86.3	0.6	35.9	145,118

¹ L_{max} = single event maximum sound level

² ASEL = A-weighted sound exposure level

CHAPTER 4

BEHAVIORAL RESPONSES OF NESTING PEREGRINE FALCONS TO LOW-ALTITUDE JET AIRCRAFT OVERFLIGHTS

Dana L. Nordmeyer Elmore, Angela G. Palmer, & Daniel D. Roby

ABSTRACT

Peregrine Falcons (*Falco peregrinus*) nesting along the Tanana River, Alaska, during the 1995–1997 breeding seasons. Animal noise monitors (ANMs) collected data on noise exposure level at 11 to 12 active nest sites annually, 6 to 9 of which were located in Military Training Routes (MTRs) and subject to low-altitude jet overflights. The majority (78%) of all observed responses by adult Peregrine Falcons to close overflights (≤ 1000 m slant distance; $n=401$) were classified as minimal, 17.5% were alert responses, and 2% were considered intense. Males generally responded more intensely to overflights than did females; only males exhibited flight responses (2.5% of all observed responses). Maximum sound pressure level, sound exposure level, and slant distance were the best predictors of falcon response to overflights and explained a significant amount of the variation in both male and female response. If acute, short-term behavioral responses of Peregrine Falcons indicate damage caused by potential disturbance, then the low level of overt behavioral responses observed in this study suggests that nesting Peregrine Falcons are only slightly affected by overflights from low-altitude jet aircraft.

INTRODUCTION

Noise disturbance of wild birds, particularly from jet aircraft, has been an issue of public concern for a number of years. A great diversity of responses to noise disturbance has been described, ranging from minor behavioral responses to drastic changes in behavior and habitat use (Manci et al. 1988, Awbrey and Bowles 1990). Flushing (taking flight) as a result of aircraft noise exposure has been documented in Spotted Owls (*Strix occidentalis*), Red-tailed Hawks (*Buteo jamaicensis*), Bald Eagles (*Haliaeetus leucocephalus*), and Peregrine Falcons (*Falco peregrinus*), as well as other nonraptorial bird species (Andersen et al. 1989, Ellis et al. 1991, Delaney et al. 1997, Grubb and Bowerman 1997, Stalmaster and Kaiser 1997). Bowles et al. (1990) postulated that an increase in flight responses induced by noise disturbance could lead to a decrease in productivity. Lower productivity could result from exposure of eggs or nestlings to stressful or lethal ambient conditions, increased predation risk, failure of the parents to care for eggs or nestlings properly, or some other unknown mechanism. Flight responses may also indicate enhanced stress levels or declining physiological condition in a breeding bird, assuming that deleterious effects of disturbance are indicated by changes in behavior (A.E. Bowles, pers. comm.).

The strong response of Peregrine Falcons to intruders near their nests is well known (Monneret 1974, Olsen and Olsen 1980). They will attack humans, bears, mink, foxes, ravens, other Peregrine Falcons, eagles, and virtually any other potential predator of their eggs or nestlings. It follows that Peregrine Falcons could respond to inanimate intruders, such as aircraft, that may be perceived by adults as threatening to their young. In fact, peregrines have been known to attack both fixed-wing aircraft and helicopters that have made close approaches to active nests during nest surveys (White and Sherrod 1973, Cade and White 1976).

The objective of this study was to evaluate the responses of nesting Peregrine Falcons to jet aircraft overflights, and then to determine which characteristics of overflights explain most of the variation in the magnitude and type of response observed. We quantified those disturbance factors (e.g., slant distance from the nest and noise level) that are believed to best explain variation in falcon responses and to assess the relative importance of other factors (e.g., sex, phase of the nesting cycle, previous experience with overflights, and nest location) that may also influence response levels.

The overall hypothesis we sought to test was that breeding Peregrine Falcons would respond more intensely to overflights as the stimuli associated with the overflights increased. We hypothesized that a direct relationship exists between intensity of disturbance—as estimated by altitude, distance, and sound exposure level (SEL)—and intensity of response (ranging from no visible response to evasive flight). We made several predictions about the characteristics of overflights that would elicit intense responses from Peregrine Falcons.

First, we predicted that louder overflights would elicit more intense behavioral responses from breeding Peregrine Falcons (Awbrey and Bowles 1990). The loudness of an overflight can be measured by the sound exposure level, or the total sound energy experienced over the duration of a noise event. Ward and Stehn (1989) found that noise level was a better predictor of behavioral responses to overflights in Brant Geese (*Branta bernicla nigricans*) than were visual cues. Brown (1990) found that responses by Crested Terns (*Sterna bergii*) depended on the noise level of simulated aircraft introduced to the colony.

Secondly, we predicted that closer jet overflights (as determined by slant distance of the aircraft from the nest) would elicit more intense responses from peregrines. Olsen and Olsen (1980) observed that Peregrine Falcons defended their nests against humans more intensely at shorter approach distances. In Spotted Owls, unlike in brant, distance generally was a better predictor of response to helicopter overflights than was sound exposure level (Delaney et al. 1997).

Based on observations by Monneret (1974), we predicted that male peregrines would respond more intensely than females during the incubation and early nestling-rearing phases. This is because females are responsible for the majority of incubation and brooding of young during these stages of the nesting cycle. Once the young are old enough for the female to leave the nest, the female begins to assume most of the nest defense while the male is out hunting. We also predicted that males would be increasingly absent (away from the nest to hunt) once the female was able to take over the defense role (Monneret 1974). When both adults are present in late season, we predicted they would respond with equal intensity.

Finally, we predicted that Peregrine Falcons that are rarely exposed to overflights would respond more intensely to the same overflight than would those in frequently overflown areas. In a Colorado study area with a long history of helicopter overflights, only 8% of red-tailed hawks flushed in response to helicopter overflights (Andersen et al. 1989). In an area where overflights were newly introduced, however, 53% of the hawks flushed. Similarly, we predicted that peregrines would respond with decreasing intensity as the number of consecutive days of overflights increased. By comparing responses of Peregrine Falcons within and among areas with different exposures to overflights, we sought to account for potential effects of habituation.

To test these hypotheses, we examined the effects of low-altitude military jet overflights on the immediate behavior of American Peregrine Falcons (*F. p. anatum*) nesting along the Tanana River, Alaska, during the 1995–1997 breeding seasons. Research on Peregrine Falcons in Alaska, particularly along the Tanana River, has historically been focused on reproductive parameters and population status (Cade 1960, White 1964, Ambrose 1989). Additionally, Ritchie (1987) investigated peregrine behavior on the Sagavanirktok River, Alaska in response to disturbances. Sample sizes, however, were small, and the effects of military jet overflights were not specifically addressed. In this study we focused on the effects of military jet overflights and analyzed relatively large sample sizes of disturbance events.

STUDY AREA

We conducted field observations of Peregrine Falcons at nest sites along the Tanana River in interior Alaska (Figure 4.1) during the summers of 1995, 1996, and 1997. The study area encompassed a 250-km (156-mi) stretch of the Tanana River between Tanacross and Salcha (from lat. 63°08'N, long. 143°36'W to lat. 64°18'N, long. 148°45'W). This stretch of the river supported over 30 active Peregrine Falcon nests, most of which were situated on cliffs overlooking the river. Three Military Training Routes (MTRs) extend across this section of the Tanana River (Figure 4.1). MTRs are air corridors where jet aircraft training exercises occur.

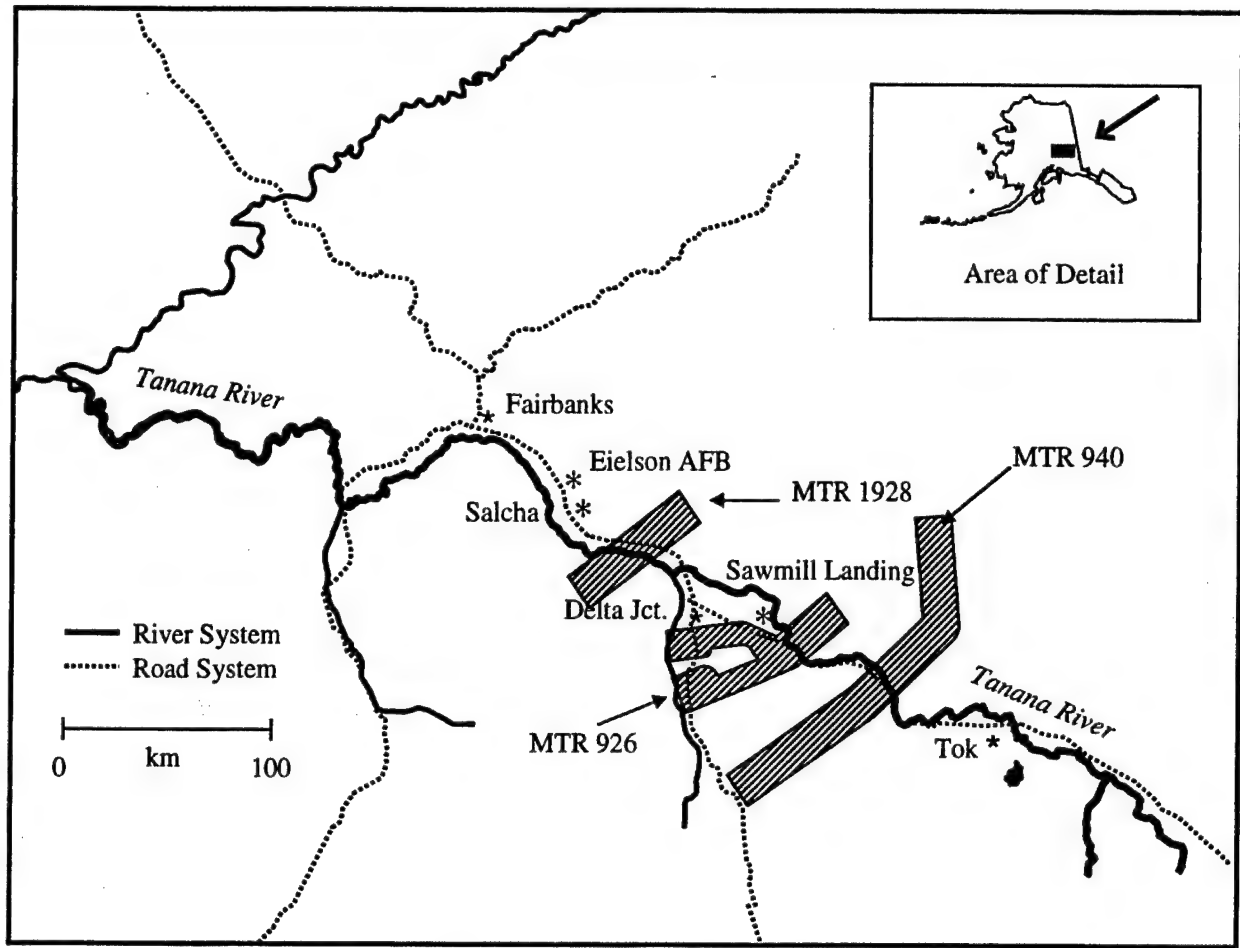


Figure 4.1 Study area along a 300-km stretch of the Tanana River between Tanacross and Salcha, east-central Alaska

During the 1995 field season, we located 13 active Peregrine Falcon nest sites along an approximately 110-km (69-mi) stretch of the Tanana River between Tanacross (km 155) and Sawmill Landing (km 305; hereafter referred to as the “upper stretch” of the study area). Of these, we selected 11 nests for observation, five nests within MTRs 940 and 926 and six nests outside the MTRs (Figure 4.1). In 1996 and 1997, the study was expanded to include another 100-km (62.5-mi) stretch of the Tanana River between Delta Junction (km 385) and Salcha (km 472; hereafter referred to as the “lower stretch” of the study area). MTR 1928 extends across the lower stretch (Figure 4.1), is located closer to Eielson Air Force Base, and is potentially subject to a higher volume of military aircraft traffic than MTRs 940 and 926. We located a total of 19 and 21 active nests in 1996 and 1997, respectively, along both stretches of river. In both years we observed six nests located in the upper stretch of the study area and six in the lower stretch. We selected nests for observation based on access to observation sites opposite cliffs and visibility of the nest ledge from the observation sites. Nests were identified by river kilometer, with kilometer zero (0) at the source of the Tanana River (confluence of Nabesna and Chisana rivers).

The Tanana River is a braided, glacially-fed river in interior Alaska. The valley floor is covered in boreal forest of predominately white spruce (*Picea glauca*), black spruce (*P. mariana*), paper birch (*Betula papyrifera*), and quaking aspen (*Populus tremuloides*), with many boggy areas and small thaw lakes. The northern bank of the Tanana River is intermittently bounded by schist and granite cliffs ranging in height up to several hundred meters. These cliffs are where Peregrine Falcons most frequently locate their nests. Some occupied cliffs overlook wide, braided areas of the river, while others are located near lakes, ponds, marshes, or other expanses suitable for hunting.

METHODS

Observations were initiated each year as soon as it was safe to travel on the river after ice break-up in mid-May, and continued until young had fledged and left the nest area (late August to early September). In 1995, we observed five nests within MTRs and six nests outside of MTRs. We observed nine nests within MTRs and three nests outside MTRs during 1996 and 1997.

Because we were working with the U.S. Air Force (USAF) on a non-interference basis (flights could not be scheduled over nests solely for the purposes of this study, but existing training missions could be slightly modified to include passes over certain nests), it was important that field crews be located within the path of as many aircraft missions as possible. Many training missions were easily modified without interfering with their main objectives.

Behavioral Observations

Field crews conducted observations of Peregrine Falcons at their nest sites during overflights by jet aircraft. Two field crews were deployed in the field in all three years of the study, although the number of observers per field crew doubled after the first year. This increase in numbers of individuals per crew from two to four allowed us to increase the number of hours of observation at each nest, while also providing better coverage during each observation session. Field crews traveled to the various nests using river boats (21- or 24-foot Alwelds with 150-hp jet outboards). Crews made observations from across at least one channel of the river, between 300 and 750 m (984 and 2460 ft) from each nest. Observation sites were generally located on sandbar islands, and, due to late-season flooding each year, observations were sometimes made at greater distances by the end of the season. Observation distance also depended on the sensitivities of each pair of peregrines to observer presence. Crews camped out of view (but within 5 km [3.1 miles]) of each observation site, but generally left equipment in a tent at each site. Approximately one hour before each session, field crews either walked or boated to the observation site. In an attempt to minimize the disturbance associated with the approach of observers, field crews approached observation

sites indirectly and along a consistent path by foot or boat. In addition, tents were used to hide observers at sites where adult birds were more sensitive to observer presence and to protect gear from inclement weather.

Behavioral observations were divided into four phases of the nesting cycle: (1) pre-incubation (including arrival of adults at the nest site, courtship, and egg-laying); (2) incubation of the eggs; (3) rearing of the young (including hatching); and (4) fledging (from the first observed flight by a nestling until all fledglings had left the nest area). In addition, we treated failed nests as a separate phase of the nesting cycle for purposes of data analysis. Most data were collected during the incubation, nestling-rearing, and fledging phases because nests were usually inaccessible before ice break-up on the Tanana River, which occurs around the peak of egg-laying.

We recorded the behavioral responses of adult Peregrine Falcons to disturbances. These observations were made with the aid of 10X binoculars, 15 to 45X spotting scopes, and Questar telescopes. We recorded responses to overflights on data sheets and with two Canon L2 Hi-8 mm video cameras. The cameras continuously recorded behavioral data during observation periods, which provided a video record of responses to overflights and other disturbances. Each camera was mounted on a tripod and equipped with a 250-mm telephoto lens, 2X teleconverter, a DC-S10 12V adapter, and a 12V deep-cycle battery. The cameras used Hi-8 mm videotapes, which recorded for up to 2 hours. One camera was focused on the nest ledge at all times. During the incubation and nestling-rearing periods, we focused the second camera on whichever adult was not at the nest ledge. If both adults were in sight, but away from the nest ledge, we focused the second camera on the female. Late in the fledging period, when the nest ledge was rarely occupied, cameras were focused on the two birds (or groups of birds) that were most easily viewed.

We recorded responses to disturbance as one of 10 categories. Definitions of these response categories, as well as their intensity ranking, were as follows:

Unknown response: Adult bird was not in view of the observers during the potential disturbance.

No response (response intensity 0): Adult bird continued previous activities, including perching, dozing, preening, feeding, or soaring.

Attentive (response intensity 1): Adult bird was aware of stimulus; looked up briefly and watched stimulus source; looked about in some cases with intermittent head movements.

Alert/alarmed (response intensity 2): Adult bird looked about in search of stimulus using quick head movements in rapid succession, followed by an intense stare in some cases; tucked leg dropped to perch in some cases.

Flight intention movement (response intensity 3): Adult bird exhibited intentions to fly but did not fly; exhibited head-bobbing, leaned forward, defecated, or raised wings.

Stand up (response intensity 3): Adult bird stood up from a crouched position, such as during incubation or brooding young.

Crouch/cower (response intensity 4): Adult bird lowered profile while perching, incubating, or brooding.

Unknown flying (response intensity 5): Adult bird flew and flight appeared to be neither defensive nor evasive; alternatively, adult left its perch, but its flight was not observed.

Defensive flying (response intensity 6): Adult bird flew as if defending the nest; usually included vocalization, diving, or attacking source of disturbance.

Evasive flying (response intensity 7): Adult bird flew in an evasive manner; as indicated by avoidance escape behavior, low profile or low altitude flight, or rapid disappearance from view.

Response intensities 0 and 1 were classified as "minimal" responses, while response intensity 2 was an "intermediate" response. Response intensities 3 and 4 were classified as "intense" responses, and response intensities 5, 6, and 7 were classified as "flight" responses.

Overflight Characteristics

Overflights of nests in the MTRs by subsonic A-10, F-15, and F-16 military jets were coordinated with existing missions of the 11th Air Force from Eielson Air Force Base (AFB; see Figure 4.1) and Elmendorf

The two F-series jets are faster, louder, and less maneuverable than the A-10. Several British jets (Harriers, Tornados, or Jaguars) involved in joint training exercises were also engaged in overflights. Before the beginning of each field season, we prepared a preliminary schedule of days when overflights could be expected at each nest (training missions, weather, and real-life military situations permitting). Overflights could not be scheduled during Cope Thunder exercises (joint training exercises occurring each summer in interior Alaska), although we did receive incidental, unscheduled overflights while Cope Thunder exercises were being conducted. During Cope Thunder periods (two weeks at a time, three to

four times per breeding season), we concentrated on baseline observations at overflowed nests, as well as observations at reference nests. Each week during potential overflight periods, we used cell phones to call the Eielson AFB scheduling office (cell coverage permitting) to receive a schedule of half-hour time blocks when we could expect overflights.

Type III Standard and Compact animal noise monitors (ANMs; Hill 1995, Kugler 1996) were deployed near active Peregrine Falcon nests for the duration of the breeding season and were used for monitoring noise levels during overflights. In addition, a portable Larson-Davis Sound Monitor 870 or an ANM was deployed near the observers in 1995. These extra sound monitors served as a backup during behavioral observations and also provided some index for checking the accuracy of cliff-deployed ANMs. Two ANMs were deployed at each active nest inside an MTR (as a backup in case of ANM failure), and only one ANM was deployed at each active nest outside an MTR. The ANMs were set to record sound levels that exceeded a threshold of 85 dBA (A-weighted decibels) and lasted more than two seconds, but less than two minutes. These settings were chosen so that the sound monitors would record noises that were likely to be caused by jet aircraft, while simultaneously screening out noises that were unlikely to be caused by jet aircraft (Kugler 1996). ANMs measured the intensity of noise events and provided back-up information on number, timing, and frequency of these events. The ANMs recorded the following noise dose variables:

- and c-weighted sound exposure level (SEL_a and SEL_c)
- duration of above-threshold sound levels
- maximum sound pressure level (L_{max})

ABR, Inc. provided technical assistance for deploying and retrieving data from ANMs. Krisand Consulting and Research (KCR; Encino, CA) screened the ANM data. All noise events recorded on the weekend (when military jet overflights only rarely occurred) and all noise events that could not be interpreted as military jet overflights were removed from the database by KCR.

Air Force personnel (Forward Air Controllers, or FACs) were present in the field during much of the 1996 and 1997 field seasons. The FACs directed scheduled flights over nests, called in extra aircraft that happened to be in the area, and helped with data collection (particularly for overflight variables such as distance, altitude, and airspeed). The FACs communicated with pilots and were often able to obtain altitude and airspeed readouts from the cockpit. They also were able to direct pilots for multiple passes at varying altitudes and angles of approach in relation to an active nest. Each pass by a jet aircraft or group of aircraft was treated as a separate overflight.

Scheduled jets were requested to fly directly over nests at altitudes between 170 m (500 ft, which was the lower limit in the MTR) and 330 m (1000 ft) above ground level (AGL), and at power settings of 90% full power. If possible, scheduled jets were asked to fly over nests from multiple directions, making several passes in succession.

We recorded the type of aircraft, altitude, and estimated minimum lateral distance from the nest for each overflight. Slant distances were calculated for each overflight by combining the minimum altitude of an overflight above a nest with the minimum lateral distance of an overflight from the nest. Close overflights, defined as ≤ 1000 m slant distance from a nest, were used to examine the effects of jet overflight parameters on behavior of Peregrine Falcons. We chose this slant distance as the criterion for a close overflight because all but one of the observed jet overflights that exceeded the thresholds of the ANMs were within 1000 m slant distance of the nest. All but one above-threshold A-10 overflight was within 500 m slant distance; F-series and British jets were louder and were picked up by the ANMs at greater distances. Additionally, only minimal responses (no response or attentive response) by Peregrine Falcons were observed for overflights beyond 1000 m slant distance.

Statistical Analysis

Graphical displays were used for preliminary examination of the data. We used the NCSS97 statistical package (Hintze 1997) to perform statistical analyses, including descriptive statistics for means, standard deviations, and ranges; regression analyses; two sample *t*-tests; Mantel-Haenszel tests; one-way ANOVAs; and Duncan's multiple comparison tests. We explored the relationship between overflight parameters (i.e., aircraft type, altitude, lateral distance, slant distance, ASEL, duration of sound, and maximum sound pressure level) and Peregrine Falcon response using multiple linear regression, while controlling for number of jets, consecutive days of above-threshold noise events, number of overflights in rapid succession (i.e., multiple passes by one aircraft or group of aircraft), sex, phase of the nesting cycle, nest-year, inclusion in an MTR, stretch of the river, and time of day.

We reported *P* values for all statistical tests. If $P \leq 0.05$, we considered the test significant. We chose to consider tests with $0.05 < P \leq 0.10$ as marginally significant to avoid type II errors. If a difference existed, we wanted to avoid the possibility of incorrectly overlooking that difference.

We chose a-weighted sound exposure level (ASEL) over c-weighted SEL as the primary noise dose variable. ASEL is often used in studies of noise effects on wildlife and is therefore convenient for comparing results among studies (Black et al. 1984, Johnson 1988, Ward and Stehn 1989). Also, ASEL is the weighting commonly used to measure aircraft noise levels and is an appropriate variable to use when

making management recommendations (Brown 1990, Hill 1995), as ASEL emphasizes those frequencies to which humans are most sensitive. Birds and humans are generally sensitive to similar sound frequencies, so a-weighting would be more appropriate than would c-weighting (Schwartzkopff 1973).

We examined altitude and lateral distance separately in regressions, and also in combination (slant distance), to account for possible "sound shadow effects" (Ward and Stehn 1989). The noise level of an overflight is not necessarily a direct inverse relationship with slant distance because of sound shadow zones caused by wind. Sound from low-altitude overflights can also be attenuated by topography ("barrier effect"; Trimper et al. 1998).

RESULTS

Jet Overflight Disturbance

A total of 1414 jet noise events, defined as any jet sound audible to the observers, were recorded by field crews at active nest sites during the course of the study (Table 4.1). Figure 4.2a shows the distribution of the 401 close (within 1000 m slant distance of a nest) military jet overflights among nest sites and years. A total of 132 (33%) of these close overflights exceeded the 85 dB threshold and were recorded by the ANMs.

A total of 878 above-threshold noise events were recorded by ANMs at all nests during the study (Table 4.2). Military jet formations generally flew over several nests while they were in the area and, although ANMs were set up at each nest, observers were present at only one nest at a time. Figure 4.2b shows the distribution of above-threshold noise events among nest sites and years. Although there were some unexplained discrepancies between ANM-recorded noises and events recorded by observers (i.e., 12 instances when observers were present at the nest site but did not record a noise event) and some of the ANMs experienced technical difficulties, these discrepancies accounted for a small percentage of ANM records (1% of all ANM records, 4% of ANM records when observers present). The ANM records generally provided an accurate measure of the level of noise exposure experienced by Peregrine Falcons on the Tanana River as a result of jet aircraft overflights (Kugler 1996).

Table 4.1 Breakdown by type of observed jet noise events at active Peregrine Falcon nests along the Tanana River, Alaska.

Total Audible Jet Noise Events 1414	Barely Audible (<15 dB) 214 Noise Events (15% of audible)				
	Military Jets of Unknown Type (>2 km and <40 dB) 470 Noise Events (33% of audible)				
	Identified Military Jets (<2 km and >40 dB) 730 noise events (51% of audible)	F15 or F16	305	Close Overflights (≤ 1000 m slant distance) 401 (55% of identified overflights)	
		A10	322		
				>85 dB recorded by ANMs 132 (33% of close overflights)	<85 dB not recorded 269 (67% of close overflights)

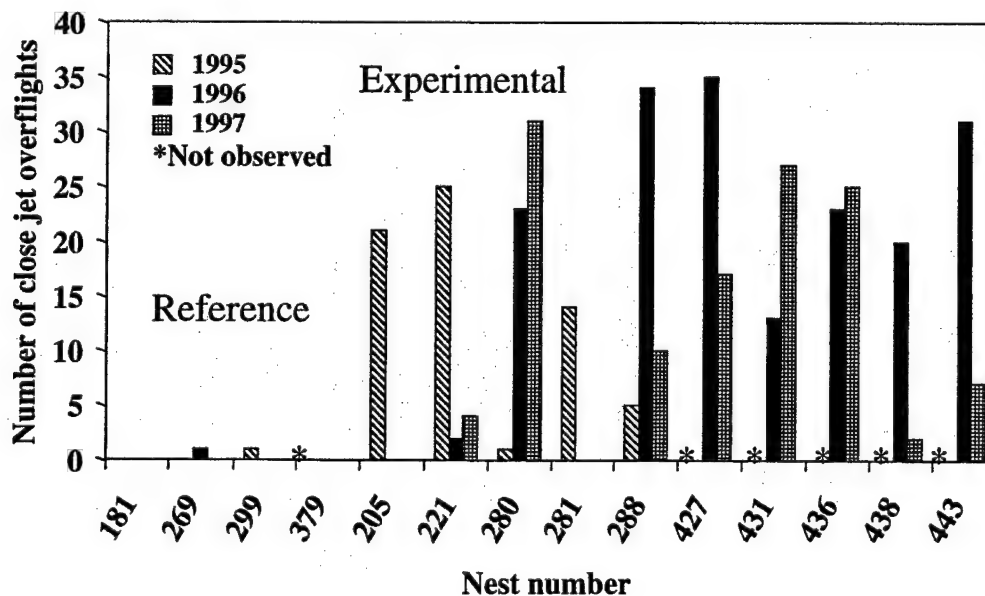


Figure 4.2a Number of close (< 1000 m slant distance from nest) military jet overflight events (n = 401) recorded by field crews at each Peregrine Falcon nest during the 1995-1997 breeding seasons along the Tanana River, Alaska.

Table 4.2 Comparison of ANM noise records and observed jet overflights at active Peregrine Falcon nests along the Tanana River, Alaska.

878 above-threshold events recorded by ANMs (≥ 85 dB)	257 above-threshold events recorded when observers were present	
		235 (91% of observed) agreed with observer records
		10 (4%) were possible matches (<5 min difference between observer log and ANM record)
		12 (4%) could not be matched; observers were present but no event was observed
	621 when observers not present	
269 close (<1000 m slant distance) overflights not recorded by ANMs	55 (20.4 %) were A10's >500 m slant distance	
	33 (12.3%) were multiple overflights in rapid succession that triggered only 1 longer-duration ANM record	
	107 (40%) were F-series jets that were not recorded by ANM, presumably because of sound shadow or sound barrier effects	
	18 (6.7%) were British jets that were not recorded by ANM, presumably because of sound shadow or sound barrier effects	

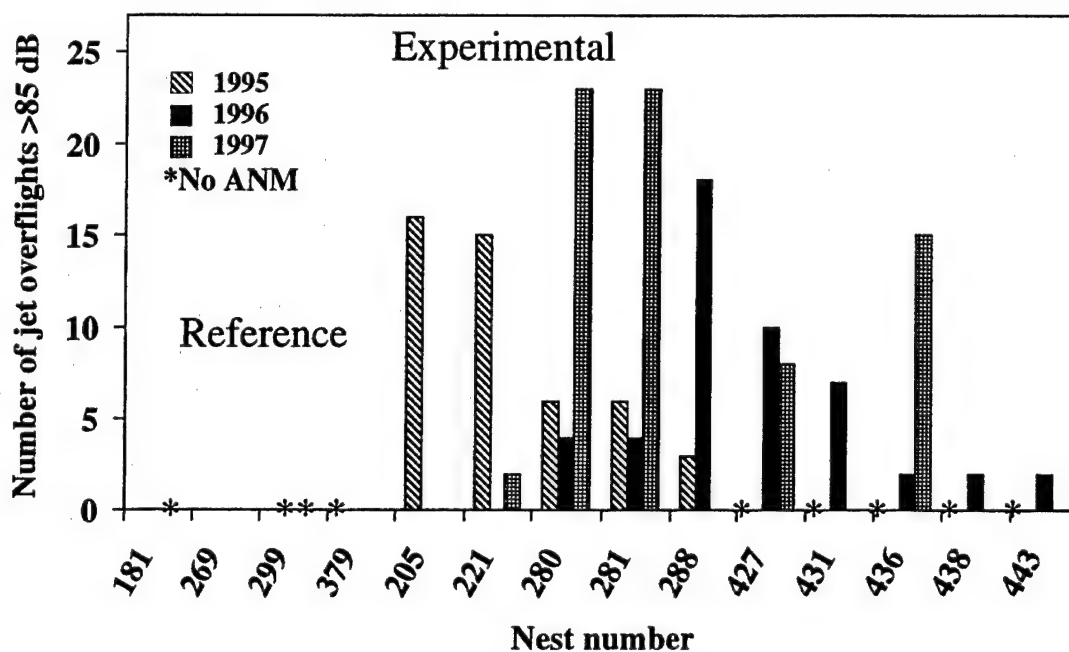


Figure 4.2b Number of jet overflight events > 85 dB noise level ($n = 878$) recorded by Animal Noise Monitors (ANMs) at each Peregrine Falcon nest during the 1995-1997 breeding seasons along the Tanana River, east-central Alaska.

Peregrine Falcon Responses to Jet Overflights

Of the 1414 jet noise events recorded by field crews, responses were observable for both the male and female parent in 508 of the events (36%; Table 4.3).

Table 4.3 *Adult Peregrine Falcon attendance at nests sites during observed jet overflights along the Tanana River, Alaska, broken down by category of overflight.*

	Audible Jet Overflights	Close Jet Overflights ($\leq 1000\text{m}$ slant distance)	Above-threshold Jet Overflights ($\geq 85\text{ dB}$)
Both male and female responses observed	508 (36%)	98 (24%)	83
Only one parent's response observed	354 (25%)	93 (23%) (only female observed)	
Neither parent's response observed	552 (39%)	210 (52%)	174
Total	1414	401	257 (when observers present)

A total of 78% of all known responses by parents to close military jet overflights were classified as minimal (response intensities 0 and 1). No flight responses by adult female Peregrine Falcons in response to jet overflights were observed, whereas eight responses by males to close overflights (5% of all male responses) were flight responses (Table 4.4).

Table 4.4 *The proportion of several behavioral reaction categories observed in response to jet aircraft overflights (slant distance $< 1000\text{ m}$) by female ($n=191$) and male ($n=98$) Peregrine Falcons during the 1995-1997 breeding seasons.*

Reaction Type	Female	Male
None	35%	35%
Attentive	48%	38%
Alert	15%	20%
Intense	2%	2%
Fly	0	5%

Response Intensity and Overflight Characteristics

To test our original hypotheses, we compared response intensity with slant distance, ASEL, and type of jet aircraft, while controlling for sex, nesting phase, and nest. We also examined the proportion of intense or flight responses by males and females as a function of slant distance, ASEL, and aircraft type. We had 83 complete records of overflights, i.e., records of observed overflights where noise level was above threshold and where the response of at least one adult falcon was visible. These data were used to investigate the relative role of ASEL for explaining variation in behavioral responses of Peregrine Falcons

to overflights. We had 508 records for audible jet overflight events when the responses of both adult peregrines were visible; 98 of these records were for close overflights. This larger data set was useful for examining the role of other overflight parameters (i.e., slant distance and jet type) in relation to falcon response.

Table 4.5 shows the relationship between overflight characteristics and response intensity. Response intensity decreased with increasing altitude of overflight. No intense responses were observed at overflight altitudes > 300 m AGL; no flight responses were observed at overflight altitudes > 240 m AGL. Response intensity also decreased with increasing lateral distance. No intense responses or flight responses were observed in response to overflights at lateral distances > 400 m. Response intensity decreased with increasing slant distance as well (Figure 4.3). Slant distance explained more of the variation in falcon response intensity than did either altitude or lateral distance alone. Slant distance alone explained 14% of the variation in male response intensity to jet overflights and 13% of the variation in female response intensity when all audible overflights were included. No alert/alarmed responses were observed in response to overflights at slant distances > 700 m, and no intense responses were observed in response to overflights at slant distances > 550 m. No flight responses were observed in response to overflights at slant distances > 400 m.

Table 4.5 *Regressions of response intensity on different factors thought to influence adult Peregrine Falcon response to military jet overflights.*

Regression of response intensity on...	Females	Males
Altitude (controlling for nesting phase and nest)	$F_{1,638} = 55.11, P < 0.001$	$F_{1,535} = 54.53, P < 0.001$
Lateral distance (controlling for same)	$F_{1,638} = 71.20, P < 0.001$	$F_{1,535} = 64.15, P < 0.001$
Slant distance (same)	$F_{1,638} = 93.74, P < 0.001$	$F_{1,535} = 84.64, P < 0.001$
SELa	$F_{1,57} = 10.10, P = 0.0024$	$F_{1,42} = 4.05, P = 0.0506$
SELa when both parents present	$F_{1,25} = 9.63, P = 0.0047$	$F_{1,25} = 1.22, P = 0.2806$
SELa (controlling for slant distance)	$F_{2,56} = 4.96, P = 0.0103$	$F_{2,41} = 2.16, P = 0.1280$
A-weighted maximum sound pressure level	$F_{1,57} = 11.29, P = 0.0014, R^2 = 0.1653$	$F_{1,42} = 3.32, P = 0.0756, R^2 = 0.0733$
Duration of sound	$F_{1,57} = 0.0093, P = 0.9236$	$F_{1,42} = 0.3386, P = 0.5638$
Number of overflights in rapid succession	$F_{1,253} = 3.68, P = 0.0561, R^2 = 0.0143$	$F_{1,226} = 10.24, P = 0.0016, R^2 = 0.0434$
Time of day	1-way ANOVA, $P = 0.1194$ for close overflights	1-way ANOVA, $P = 0.5444$ for close overflights
Year	1-way ANOVA, $P = 0.1194$ for close overflights	1-way ANOVA, $P = 0.5444$ for close overflights

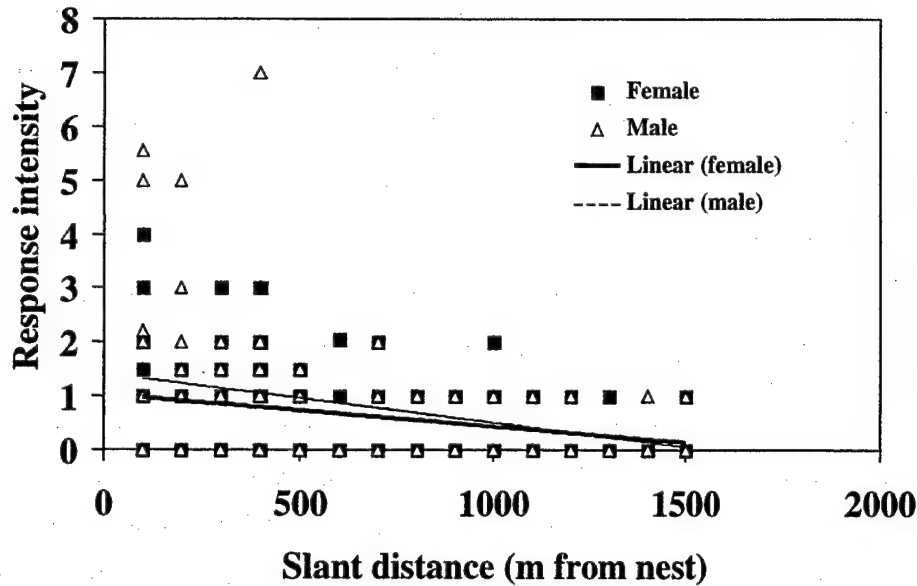


Figure 4.3 Mean female ($n = 731$) and male ($n = 636$) Peregrine Falcon behavioral reactions to jet aircraft overflights as a function of slant distance. Reaction intensities, in order from 0-7, were: no reaction, attentive, alert/alarmed, stand/flight intention movement, crouch/cower, unknown flight, defensive flight, evasive flight.

Response intensity increased with increasing a-weighted maximum sound pressure level, but not with increasing duration of sound. Response intensity increased with increasing a-weighted sound exposure level (ASEL; Figure 4.4).

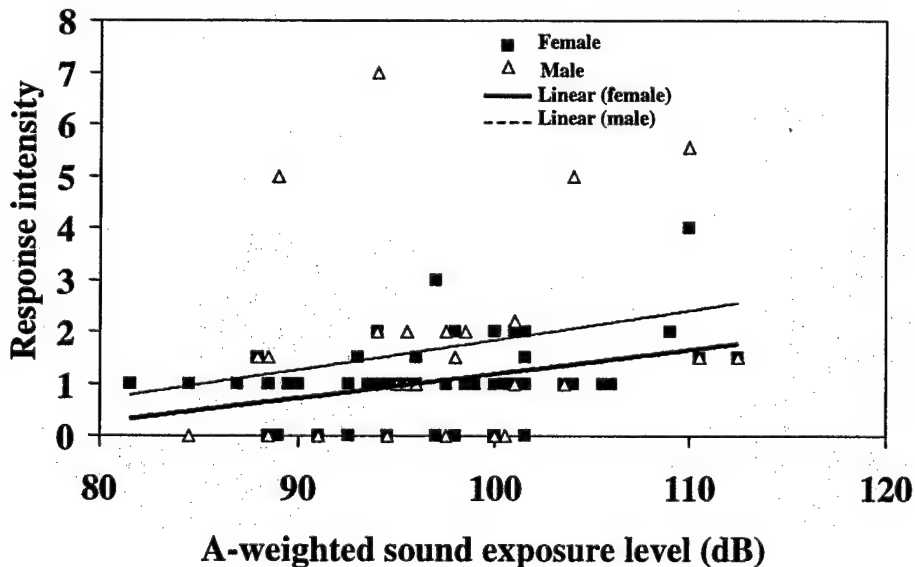


Figure 4.4. Female ($n = 63$) and male ($n = 47$) Peregrine Falcon behavioral reactions to jet aircraft overflights as a function of a-weighted sound exposure level (ASEL). Reaction intensities, in order from 0-7, were: no reaction, attentive, alert/alarmed, stand/flight intention movement, crouch/cower, unknown flight, defensive flight, evasive flight.

ASEL explained 15% of the variation in female response intensity to above-threshold jet overflights and 10% of the variation in male response intensity. All intense or flight responses observed when ANMs were present and functioning occurred when $ASEL \geq 89.0$ dB (mean = 100.5 dB, range = 89.0–110.3 dB, $n = 14$).

F-series and British jets produced higher ASEL's on average than did A-10s, even after controlling for slant distance ($F_{1,130} = 9.03$, $P = 0.0032$), and airspeeds were greater as well. Type of jet, however, did not affect reaction intensity after controlling for slant distance and ASEL.

The number of aircraft in an overflight formation (i.e., 1-ship, 2-ship, 4-ship, 8-ship) also did not explain a significant proportion of the variation in Peregrine Falcon response intensity. There was, however, a positive correlation between number of overflights in rapid succession (number of passes by the same aircraft within 10 minutes) and response intensity. Neither time of day nor year explained a significant proportion of variation in response intensity for either sex.

Response Intensity and Peregrine Falcon Characteristics

Males exhibited a higher proportion of intense responses to jet overflights than did females (Figure 4.5). When both males and females were present during an overflight, the response intensity of males was significantly higher than for females (1-tailed paired t -test, $P = 0.0002$, $df = 1014$).

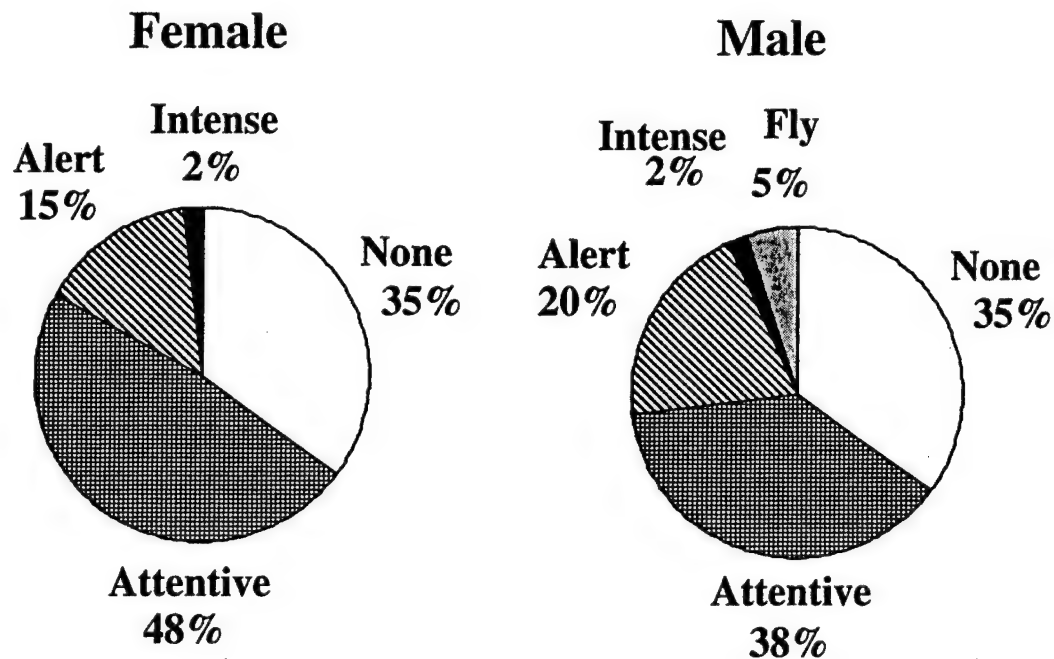


Figure 4.5 Reactions of Male and Female Peregrine Falcons

Males also exhibited significantly more flight responses than did females (1-tailed paired t -test, $P = 0.0041$, $df = 1012$, Figure 4.5). In fact, females were not observed exhibiting any flight responses as a result of jet overflights during the course of the three year study. We observed significant gender differences in the relationship between response intensity and slant distance, and between response intensity and ASEL (Figures 4.3 and 4.4, Table 4.6). More intense reactions on the part of males were not apparent, however, at failed nests or once young were capable of flight.

Table 4.6 *Influence of phase of the nesting cycle on gender differences in response intensity by adult Peregrine Falcons to military jet overflights.*

Phase of the Nesting Cycle	Male vs. Female Response Intensity
Incubation:	male > female 1-tailed paired t test, $P = 0.0029$, $df = 152$
Nestling-rearing:	male > female 1-tailed paired t test, $P = 0.0071$, $df = 348$
Fledging:	male = female 1-tailed paired t test, $P = 0.4840$, $df = 120$
At failed nests:	male = female 2-tailed paired t test, $P = 0.5669$, $df = 160$
Males: incubation and nestling-rearing > fledging and at failed nests (for close overflights) $F_{3,150} = 3.01$, $P = 0.0322$	
Females: incubation=nestling-rearing=fledging=at failed nests (for close overflights) $F_{3,188} = 1.82$, $P = 0.1452$	

Response intensities of males were greater during incubation and nestling-rearing than during fledging and at failed nests, whereas responses of females were only slightly more intense during these early stages of the nesting cycle. No intense or flight responses were observed in reaction to overflights during fledging, regardless of sex (Figure 4.6).

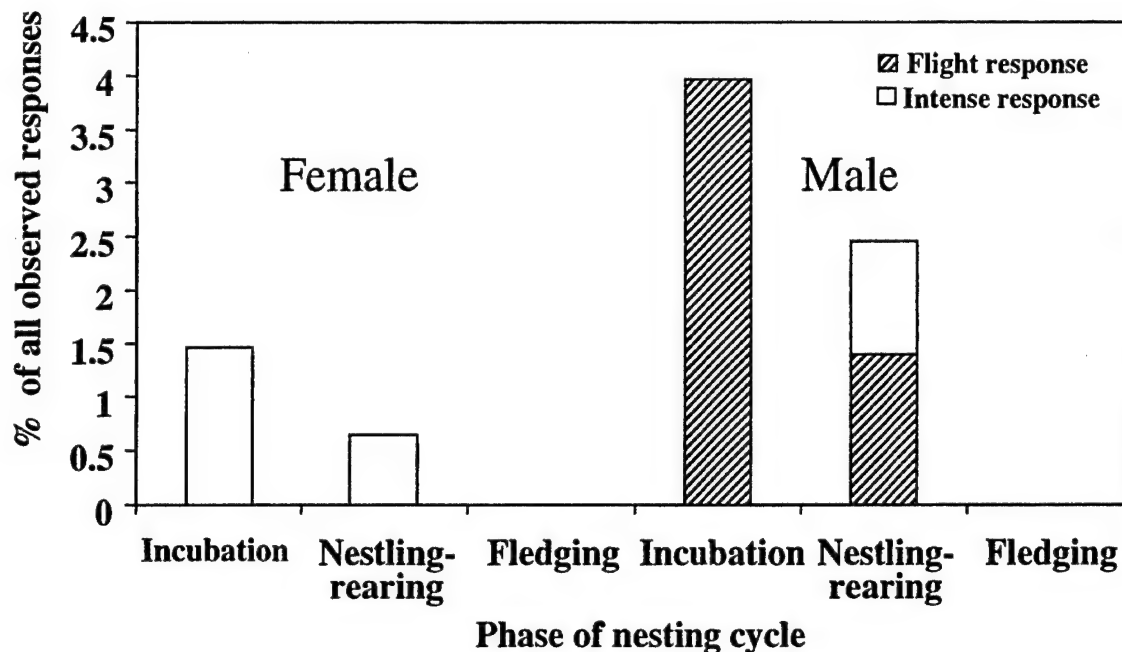


Figure 4.6. Proportion of known intense (stand, flight intention movement, or crouch/cower) or flight reactions by female and male Peregrine Falcons to all audible jet aircraft overflights as a function of phase of the nesting cycle.

To better examine gender differences in response intensity during each phase of the nesting cycle, we calculated a derived variable from the difference in the male's response and the female's response for each overflight where both parents were visible. Gender differences in response intensity were greatest during incubation.

There was not a sufficiently large sample of banded adult Peregrine Falcons among the study nests to test for significant effects of individual exposure history on intensity of response to overflights. To assess the role of habituation as a factor influencing response intensity, we instead examined response intensity as a function of consecutive days of above-threshold noise events and consecutive days of close jet overflights. These two independent variables were identical and did not explain a significant proportion of the variation in response intensity (females: $F_{1,190} = 0.418$, $P = 0.8382$; males: $F_{1,152} = 0.4337$, $P = 0.5112$). Response intensity to similar overflights also did not differ between nests within and outside MTRs (2-tailed, 2-sample t -test, females, $df = 190$, $P = 0.5422$; males, $df = 152$, $P = 0.8591$), where differences in previous exposure to overflights would be expected. Differences in reaction intensity were also not found between nests located on the upper stretch of the Tanana River study area (less frequent overflights) compared with those located on the lower stretch (2-tailed, 2-sample t test, females, $df = 190$, $P = 0.6598$; males, $df = 152$, $P = 0.3954$). We were unable, therefore, to find evidence of a habituation effect on response intensity for either sex.

Complete Model

The factors that explained a significant proportion of the variation in response intensity of adult Peregrine Falcons to jet overflights were sex, slant distance, a-weighted sound exposure level (ASEL), a-weighted maximum sound pressure level (Lmax), number of overflights in rapid succession, and phase of the nesting cycle (Table 4.7). When we ran a stepwise regression on these five factors for the overflights with complete records (i.e., included noise level measurements), the complete model for females included only Lmax. Nothing was significant for males. When we ran a stepwise regression on slant distance, number of overflights in rapid succession, and phase of the nesting cycle for all close overflights (to increase sample size), the complete model included slant distance for both females and males. In addition, for males the complete model for all close overflights included number of overflights in rapid succession.

Table 4.7 *The stepwise regression of response intensity by nesting adult Peregrine Falcons exposed to low-altitude jet aircraft overflights on the five factors found to have an individual correlation with response (complete model). R^2 , F , and P -values given for significant or marginally significant factors ($P \leq 0.05$ = significant, $0.05 < P \leq 0.10$ = marginally significant).*

Factors Potentially Explaining Variation in Reaction Intensity of Adult Peregrine Falcons	Females ¹	Males ¹	Females ²	Males ²
Slant distance	not significant	not significant	$R^2=0.0559$, $F_{1,190}=11.25$, $P=0.0009$	$n=154$, partial $R^2=0.0613$
SELa (a-weighted sound exposure level)	not significant	not significant		
Lmax (a-weighted maximum sound pressure level)	$R^2=0.1735$, $F_{1,56}=11.76$, $P=0.0011$	not significant		
Number of overflights in rapid succession	not significant	not significant	not significant	$R^2=0.0936$, $F_{2,151}=7.80$, $P=0.0005$
Phase of the nesting cycle	not significant	not significant	not significant	not significant

¹when all five factors were included in a stepwise regression for those overflights that included noise level measurements

²when only slant distance, number of overflights in rapid succession, and phase of the nesting cycle were included in a stepwise regression for all close overflights (in order to increase sample size)

DISCUSSION

Breeding Peregrine Falcons generally exhibited more intense behavioral responses to jet overflights as the stimulus strength associated with the overflight increased. Both male and female peregrines responded with increasing intensity to overflights of decreasing altitude, lateral distance, and slant distance in relation to their nests. In addition, response intensity increased with increasing ASEL.

The highly significant negative correlation between Peregrine Falcon response intensity and slant distance indicates that peregrines exhibit more intense responses the closer the jet approaches the nest, in agreement with other studies (Olsen and Olsen 1980, Johnson 1988, Ward and Stehn 1989, Yalden and Yalden 1989, Grubb and Bowerman 1997). Slant distance, however, only explained about 6% of the variation in response intensity to close overflights (≤ 1000 m slant distance) for either sex, when other variables were taken into consideration.

A-weighted SEL was a significant source of variation in female Peregrine Falcon response to overflights, and marginally significant for males. Males responded intensely to overflights at all measurable ASEL levels (> 85 dB). This supports the hypothesis that the greater average response intensity of males is related to their greater role in nest defense throughout most of the breeding season. Male response intensity may be more closely related to visual cues than to auditory ones, as they are normally perched near the nest where vantage is good. Females, on the other hand, are more frequently at the nest ledge, where the view of the surroundings can be restricted. The sample of overflights with ASEL measurements is a small sample of very close and very loud overflights. This helps explain why female response intensity varied with noise level, while male response intensity did not.

Duration of sound did not significantly affect intensity of Peregrine Falcon responses to overflights. This likely reflects a greater sensitivity by the birds to the maximum noise level experienced, rather than the duration of sound.

We predicted that males would respond to overflights more intensely than females during incubation and nestling-rearing because males are usually responsible for nest defense and females normally sit tight while brooding eggs or nestlings (Monneret 1974). Clear differences were detected in the responses of male and female peregrines to jet overflights. These differences are probably related to the pronounced sexual dimorphism in Peregrine Falcons and differences in the roles of the two sexes during reproduction (Monneret 1974). Males displayed higher frequencies of both intense and flight responses than did females in each year of the study. The mean intensity of male responses was also higher than that of females. Cade and White (1976) found that incubating Peregrine Falcons responded less to disturbance

than did non-incubating peregrines, and that it was difficult to get an incubating peregrine to move off the nest scrape (the depression on the nest ledge in which eggs are laid).

During the fledging phase, neither sex responded as intensely to overflights, and there was no gender difference in response intensity. This could be a result either of habituation by males to overflights or a decrease in defensiveness of the nest and young by parents once the young have fledged.

The response intensity of males to jet overflights did not differ between those whose nest had failed and those whose young had fledged. The response intensity of males in either case was significantly less compared to males caring for eggs or nestlings. This supports Olsen and Olsen's (1980) finding that defensive behaviors were greatest when a pair had eggs or nestlings. They also found that although non-breeding pairs defended their territory on occasion, they normally did not.

Males tended to respond more intensely to overflights than did females, regardless of location of the nest, time of day, or noise level of the overflight. Besides slant distance, the one factor that explained a significant proportion of variation in male response intensity was the number of aircraft overflights in rapid succession (number of passes). The number of passes was positively correlated with intensity of male response. Perhaps repeated passes increased the stress level of males or sensitized them to additional passes, at least in the short-term.

Females did not respond as strongly or as often as males. Slant distance was the only variable that explained a significant proportion of the variation in female response intensity. There was more variation in response intensity among individual females compared to males. Perhaps females responded most when their mate needed assistance (or when the male was not present) because the cost of flight responses may be high in terms of exposing eggs or young. The cost of flight responses by males is presumably low while the female is on the nest, and so they may react more intensely to a wider range of jet overflight intensities. To examine this possibility, we ran an ANOVA on responses of females to close jet overflights when males were present versus when they were absent. The mean response intensity of females was significantly greater when their mates were out of sight of the observers ($F_{1,185} = 8.08$, $P = 0.0050$).

The lack of a difference in response intensity between Peregrine Falcons whose nests were within MTRs and those whose nests were not can be partly explained by the paucity of overflights at some nests located within MTRs. Three nests within MTRs were exposed to less than 10 above-threshold overflights in a given season. Also, five nests within MTRs were exposed to less than 15 audible overflights during observation periods in a given season. Conversely, nests outside MTRs were sometimes exposed to

significant numbers of overflights. Three nests outside of MTRs were exposed to more than 10 overflights that exceeded the 85 dB threshold of the ANMs in a single season.

The lack of a difference in response intensity between nests within and outside MTRs suggests that Peregrine Falcons are experiencing neither habituation nor sensitization at this level of exposure to jet overflights. If Peregrine Falcons tended to habituate to jet overflights, one would expect a lower average response intensity from those peregrines nesting in flight corridors (i.e., MTRs) than from those nesting in areas where jets are subject to altitude restrictions. If peregrines were, on the other hand, sensitized to jet overflights, one would expect a higher average response intensity from those peregrines nesting in flight corridors.

Of all the overflight parameters, noise parameters such as Lmax and ASEL were the best predictors of response intensity of nesting Peregrine Falcons to jet aircraft overflights. Lmax was a better predictor of response intensity than was ASEL, but Lmax only explained 7% and 17% of the variation in male and female response intensities, respectively. In the absence of data on noise level, slant distance of the aircraft from the nest was the best predictor. Even with the numbers of loud, close overflights observed in this study, however, intense responses by Peregrine Falcons to military jet overflights were rarely observed. If acute, short-term behavioral responses indicate damage caused by disturbance, then the observed low level of overt behavioral responses to jet aircraft overflights by nesting Peregrine Falcons suggests a low overall sensitivity to this potential source of disturbance. Despite the significant contribution of slant distance, noise exposure, sex, and phase of the nesting cycle in explaining variation in response intensity to jet overflights, most of the variation remained unexplained and was presumably related to individual differences in sensitivity to overflights.

CONCLUSIONS

Behavioral responses of nesting peregrine falcons to potential disturbances from military jet overflights were classified as intense for purposes of this study when the response included (1) taking flight from the nest or the vicinity of the nest, (2) standing up while incubating or brooding young, or (3) crouching and/or cowering while on the nest or in the vicinity of the nest. Breeding adult peregrine falcons rarely exhibited intense behavioral responses to jet overflights, even at slant distances less than 500 m [1640 ft] from the nest. Breeding peregrine falcons exhibited no intense behavioral responses at slant distances greater than 550 m [1804 ft] from the nest.

For those jet overflights where measurements of both slant distance and noise levels at the nest were available, we found that noise level was a better predictor of response intensity by nesting peregrine

falcons than slant distance. When no noise measurements were available, slant distance was clearly the next best predictor of response intensity to overflights.

Female peregrine falcons were not observed to fly in response to jet overflights, and the mean response intensity of nesting females was lower than that for nesting males. These gender differences appeared to be related to differences in the roles of the two sexes during nesting. Females brooding eggs or young nestlings responded less intensely to jet overflights than did males, probably because of females' dominant role in protecting offspring at the nest ledge, whereas males generally assume more the role of attacking intruders within the nest area.

Most of the variation in response intensity of nesting peregrine falcons to jet aircraft overflights remained unexplained, suggesting that differences among nesting individuals in sensitivity to jet overflights may be significant.

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CHAPTER 5

EFFECTS OF JET AIRCRAFT OVERFLIGHTS ON NESTING SUCCESS OF PEREGRINE FALCONS: RELATIVE ROLES OF DISTURBANCE DOSE AND BEHAVIORAL RESPONSE

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ABSTRACT

Behavioral responses of nesting raptors to potential disturbances have been used as indicators of the impact of disturbance on nesting success. The purpose of this study was to determine if the intensity of immediate behavioral responses by breeding Peregrine Falcons (*Falco peregrinus*) to jet aircraft overflights is associated with lower nesting success. Field crews observed behavioral responses of peregrines to overflights at 12 active nests along the Tanana River, east-central Alaska, during the 1995, 1996, and 1997 breeding seasons. Military jet aircraft flew at low-altitudes over nest sites under observation (experimental nests); other nests were not intentionally overflown (reference nests). Nest productivity (number of young raised per nesting attempt) did not differ between experimental and reference nests and was within the normal range for Peregrine Falcons nesting in east-central Alaska. Productivity also did not differ between nests exposed to >20 close overflights per season compared with those exposed to <20 close overflights per season, nor between nests with an average daily sound exposure level (SELa) of >90 dB compared with those with average daily SELa of <90 dB. The apparent lack of an effect of military jet overflights on nesting success was associated with the generally low intensity of response by adult Peregrine Falcons to overflights (see Chapt. 4). There were, however, significant differences among individual nesting peregrines in the intensity of response to overflights. Furthermore, the average response of Peregrine Falcons to overflights was negatively correlated with productivity and explained a significant proportion of the variation in productivity among nests. These results suggest that the intensity of response by breeding Peregrine Falcons to low-altitude jet overflights is a better indicator of subsequent productivity than the actual dose of overflight disturbance. The available evidence supports the hypothesis that higher response intensity is associated with lower parental investment, presumably in younger, less experienced parents, and the productivity of these parents is generally lower.

INTRODUCTION

In this study we sought to determine if the observed behavioral responses of nesting Peregrine Falcons to low-altitude jet aircraft overflights were correlated with subsequent nesting success. We tested the hypothesis that the magnitude of behavioral responses of nesting Peregrine Falcons to jet aircraft overflights was associated with detectable reductions in nesting success, and therefore represents a measurable cost for the current reproductive attempt. This hypothesis

predicts that the frequency and intensity of behavioral responses to disturbance are negatively correlated with nesting success and productivity of breeding Peregrine Falcons. If this hypothesis is supported, the sensitivity of parent Peregrine Falcons may be a better predictor of the magnitude of disturbance than the actual dose of potential disturbance (i.e., frequency and intensity of overflights). An alternative hypothesis is that Peregrine Falcons that react more intensely to jet aircraft overflights have a high motivation to defend young, which is indicative of a high level of parental investment in the current reproductive attempt. This hypothesis predicts that the frequency and intensity of behavioral responses to disturbance are positively correlated with nesting success and productivity.

Human disturbance of wildlife can be defined as any human activity that raises the energetic costs of survival and/or reproduction, and thus lowers either one or both of these measures of individual fitness (Neil et al. 1975). One potential link between a disturbance and its effect on productivity of wildlife is its immediate effect on behavior. Flemming et al. (1988) found that disturbance-induced behavioral changes in Piping Plover chicks (*Charadrius melodus*) led to increased chick mortality. Hamm (1967) attributed aircraft noise-induced reductions in egg production of domestic fowl to changes in breeding behavior, not to stress-related physiological changes. Similarly, Stadelman (1985) found that an isolated low-altitude overflight triggered a violent behavioral response in poultry, which resulted in chick loss.

It has been well documented that low-altitude aircraft overflights affect the normal behavior of wildlife and elicit a variety of behavioral responses (Andersen et al. 1989, Ward et al. 1994, Ellis et al. 1991, Maier et al. 1998). A provisional model for effects of jet aircraft overflights on nesting success of raptors was proposed by Awbrey and Bowles (1990), and was based on the assumption that the immediate behavioral responses to aircraft noise (i.e., flight response) may cause lower productivity in raptors. If so, the magnitude of behavioral response to overflights should have measurable effects on nesting success of raptors. In other words, it should be possible to assess the magnitude of disturbance and the corresponding deleterious effects on survival and reproduction by measuring the responses of raptors to jet aircraft overflights.

METHODS

Study Design

We conducted field observations of Peregrine Falcons at nest sites along the Tanana River in east-central Alaska during the summers of 1995, 1996, and 1997. These on-river nests are

situated on cliffs overlooking the river. See Chapter 1 of this report for a detailed description of the study area, and Chapter 4 of this report for a detailed description of the design for the on-river portion of this study.

Data Collection

Field crews recorded data on jet aircraft overflights and the responses of Peregrine Falcons to the overflights. See Chapter 4 for details of data collection on overflight characteristics, noise levels at active nests, and the behavioral responses of nesting Peregrine Falcons.

Nesting productivity data (i.e., number of fledglings raised per nesting attempt) were collected during observations of nests and during two visits to each active nest in each breeding season. The first nest visit took place in early to mid-May (depending on timing of river break-up and ice conditions) to perform an occupancy check, install Animal Noise Monitors (ANMs), and determine clutch size (if possible without causing excessive disturbance to the breeding pair). The second nest visit took place in mid- to late July to check productivity, band young, and collect prey remains. This later productivity check coincided with the mid nestling-rearing phase, when the young are least vulnerable to disturbance because they are capable of thermoregulation but do not attempt to leave the nest scrape.

The following nesting success and productivity variables were measured for each nest under observation:

Hatch date: Median date on which eggs hatched. This date was used to estimate laying date by back-dating. If hatch date was not determined, hatch date was estimated by back-dating from estimated age of nestlings at banding.

Nestling survival: Proportion of hatchlings that survived to 25 days post-hatch.

Nesting success: Whether a breeding pair successfully fledged at least 1 young.

Productivity: Number of young fledged per nesting attempt.

Data Analysis

General statistical procedures followed those described in Chapter 4 of this report. In addition to separating study nests into either "experimental nests" (nests within a Military Training Route [MTR]) or "reference nests" (nests outside an MTR), we separated all study nests into either

“many overflights” or “few overflights” categories. Some experimental nests were exposed to fewer overflights than some reference nests because they were located in portions of MTRs that were rarely used. Nests in the “many overflights” category were those exposed to at least 20 close overflights during a breeding season ($n = 12$ nest years). Close overflights were defined as those that came within 1000 m slant distance of the nest. Nests in the “many overflights” category experienced a median of 27 close overflights, whereas nests in the “few overflights” category experienced a median of 2 overflights ($n = 13$ nest years). In addition, we categorized study nests as either “high noise” or “low noise.” Nests in the “high noise” category were those that had an average daily A-weighted sound exposure level (SELa) of at least 90 dB during the breeding season (median = 98.9 dB, $n = 21$ nest years), and those in the “low noise” category had an average daily SELa of less than 90 dB (median = 78 dB, $n = 14$ nest years). The “high noise” category also included nests that experienced at least 10 above-threshold noise events (> 85 dB) during a breeding season. Finally, to check the validity of combining data from the different years of the study and from the two parts of the study area (upper and lower stretches of the Tanana River; see Chapter 4), we compared the average success and productivity of nests among years and from these two areas.

We developed an index of the intensity of the behavioral response to jet overflights by breeding adult Peregrine Falcons in order to quantify variation in the magnitude of response by individual birds to this type of potential disturbance. This response index was designed to measure the intensity of behavioral responses to overflights, after controlling for variation in overflight intensity. Based on the results in Chapter 4, slant distance from the nest was used to measure overflight intensity. We knew that average response intensity differed between the sexes (see Chapter 4), so response indices were calculated separately for each sex. The response index for each Peregrine Falcon was calculated by first regressing the intensity of behavioral responses to overflights against the slant distance of the overflight for the entire population of Peregrine Falcons (separately by sex). We then calculated the residuals of response intensity as a function of slant distance for each individual falcon and then took the mean of the residuals. Each individual’s mean residual was treated as an index to the magnitude of that individual’s overall response to overflights (“response index”).

Statistical Analysis

We used one-way ANOVA to test for differences in response index among individuals. Next, we ran Duncan’s multiple-comparison tests to determine which individual response indices were different. We then compared the response indices of individual peregrines in experimental versus

reference categories, "many overflights" versus "few overflights" categories, and "high noise" versus "low noise" categories.

To determine whether response index and nest success were related, we performed correlation analyses on the response index versus several variables related to nest success (hatch date, nestling survival, nesting success, and productivity). We also performed correlation analyses on the combined response indices for each female and its mate to test for associations between members of a pair.

RESULTS

Peregrine Falcon Productivity

Average productivity (number of young fledged per nesting attempt) for on-river nests included in the 3-year study was 1.94 fledglings ($sd = 1.28$, range = 0–4, $n = 35$ nest years). This was well within the normal range for east-central Alaska and the Tanana River (see Chapter 2 of this report). Average productivity of experimental nests (1.96 fledglings, $sd = 1.40$, range = 0–4, $n = 23$ nest years) was not different from that of reference nests (1.92 fledglings, $sd = 1.08$, range = 0–4, $n = 12$ nest years; 2-tailed, 2-sample t test, $P = 0.9264$, $df = 28$). There were also no differences in productivity among years ($F_{2,32} = 1.32$, $P = 0.2817$), between nests in the "many overflights" (> 20 overflights per year that were ≤ 1000 m slant distance) and "few overflights" categories (2-tailed, 2-sample t test, $P = 0.9342$, $df = 21$), nor between the "high noise" (average daily SELa ≥ 90 dB) and "low noise" categories (2-tailed, 2-sample t test, $P = 0.8383$, $df = 26$). Additionally, no significant differences were found for nestling survival, nesting success, or hatch date between the various pairs of nest categories (Table 5.1). Nestling survival and nesting success were, however, significantly higher in the upper stretch of the study area than in the lower stretch (Table 5.1, Figure 5.1). When data from all 3 years were combined, the productivity of study nests in the upper stretch was about twice that of nests in the lower stretch (2.35 fledglings per nest, $sd = 1.07$, $n = 23$, range = 0–4 and 1.17 fledglings per nest, $sd = 1.34$, $n = 12$, range = 0–4, respectively; 1-tailed, 2-sample t test, $P = 0.0079$, $df = 19$; Table 5.1, Figure 5.1).

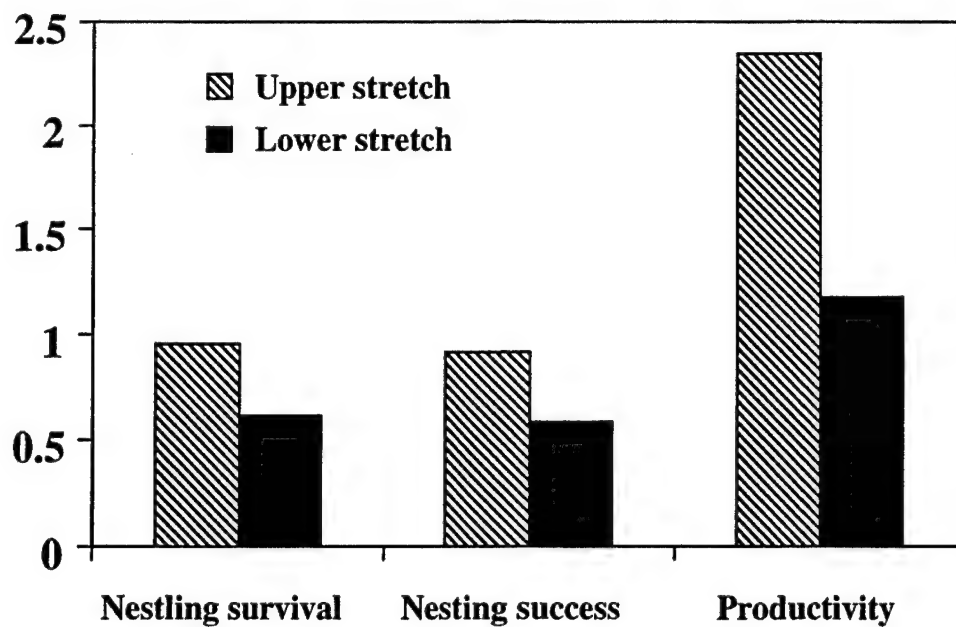


Figure 5.1 Measures of Peregrine Falcon reproductive success on the two stretches of the Tanana River included in the study area, east-central Alaska, 1995-1997

Table 5.1 *Peregrine falcon nesting success and productivity along the Tanana River between Tok and Salcha, Alaska, during the 1995–1997 breeding seasons in relation to treatment group.*

Nest treatment	Median hatch date ^a	Avg. nestling survival ^b	Avg. nesting success ^c	Avg. productivity ^d	n
Experimental nest ^e	6/20 $P = 0.1610$	0.75 $P = 0.1991$	0.74 $P = 0.3800$	1.96 $P = 0.9264$	23
Reference nest	6/17	0.91	0.92 (Fisher's)	1.92	12
Upper stretch ^f	6/20 $P = 0.3232$	0.95 $*P = 0.0389$	0.91 $*P = 0.0331$	2.35 $*P = 0.0158$	23
Lower stretch	6/17	0.61	0.58 (Fisher's)	1.17	12
Many overflights ^g	6/21 $P = 0.2251$	0.78 $P = 0.7171$	0.75 $P = 0.6697$	1.92 $P = 0.9342$	12
Few overflights	6/19	0.83	0.83 (Fisher's)	1.96	23
High noise ^h	6/20 $P = 0.3764$	0.74 $P = 0.1453$	0.76 $P = 0.6818$	1.90 $P = 0.8383$	21
Low noise	6/18	0.92	0.85 (Fisher's)	2.00	13
1995	6/19	0.92	1.00	2.40	11
1996	$X^2 = 0.0862$	$F_{2,32} = 0.40$		$F_{2,32} = 1.32$	
1997	6/19 $P = 0.9578$ (Kruskal-Wallis)	0.77 $P = 0.6727$ (1-way ANOVA)	0.62	1.54 $P = 0.2817$ 1-way ANOVA	12
	6/20	0.78	0.83	2.00	12
Total		0.81	0.80	1.94	35

*Denotes significance. P values obtained from 2-tailed, 2-sample t tests (Wilcoxon signed-rank test in the case of hatch date) unless otherwise noted.

^aHatch date estimated in some cases by back-dating from estimated age of young at banding. ^bProportion of hatchlings that survived to 25 days post-hatch. ^cWhether a nesting pair successfully fledged at least 1 young. ^dNumber of young fledged per nesting attempt. ^eLocated within an MTR. ^fLocated in the upstream stretch of the Tanana River, between Tok and Sawmill Landing. ^gReceived ≥ 20 close overflights by military jets during a breeding season. ^hExperienced daily average sound exposure level ≥ 90 dB during a breeding season.

Peregrine Falcon Responses to Overflights

A total of 191 close overflights by F-15, F-16, A-10, or British fighter jets were recorded where responses were observed for at least one member of the breeding pair of Peregrine Falcons (see Chapter 4 of this report for a detailed description of the overflights). Of these, 35% of responses were listed as "no response," whereas 43% were categorized as attentive, meaning that the adult noticed the overflight, but did not respond strongly. Alert responses accounted for 17.5% of all known responses to close overflights; only 2% of all responses were classified as stand, crouch/cower, or flight intention movement. No flight responses by adult female peregrines were observed in response to jet aircraft overflights, whereas 8 responses by males (5%) were flight responses (see Chapter 4 of this report for details of the responses to jet overflights).

Peregrine Falcon Productivity in Relation to Behavioral Responses

There was no correlation between the number of observed flight responses to military jet overflights and productivity ($F_{8,25} = 0.96$, $P = 0.4889$). Females were not observed to fly in response to military jet overflights, so the results of this analysis hold for both individual males and for mated pairs.

We calculated a response index (average residual for each individual from the regression of response intensity versus slant distance) for males and females separately (Figure 5.2). There were significant differences among females in the response index (1-way ANOVA, $P = 0.0030$). Of the 22 nest-years, 13 had negative response indices and 9 had positive response indices (mean = -0.0037, $n = 189$, range = -1.25 to 1.31). The response index did not differ significantly among individual males (1-way ANOVA, $P = 0.4061$).

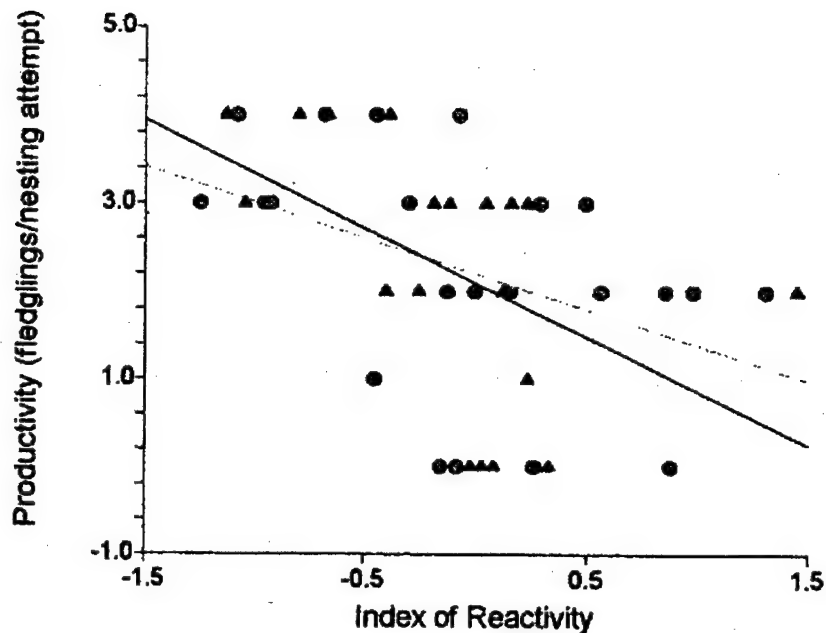


Figure 5.2 Productivity (number of young fledged per nesting attempt) of Peregrine Falcons in relation to intensity of response (see text for calculation method of response index) to low-altitude jet aircraft overflights along the Tanana River, east-central Alaska.

Positive response indices indicate a greater-than-average intensity of response to overflights, after controlling for slant distance and gender, and negative indices indicate a lower-than-average response intensity. For either males or females, there was no significant difference in the average response index for adults from the upper stretch compared with adults from the lower stretch of the study area (Mantel-Haenszel; females, $P = 0.6919$; males, $P = 0.8755$). There was also no difference in response index between females from experimental nests compared with females from reference nests ($P = 0.7364$; analysis for males precluded by small sample size). Similarly, there was no difference for adults from nests in the "many overflights" category compared with those from nests in the "few overflights" category (females, $P = 0.7278$; males, $P = 0.3253$), or for those in the "high noise" category compared with those in the "low noise" category (females, $P = 0.8809$; analysis for males precluded by small sample size).

Hatch date was not correlated with the response index for either males ($P = 0.5341$) or females ($P = 0.2687$), and neither was nesting success (males, $P = 0.4059$; females, $P = 0.2581$). Nestling survival was also not correlated with response index for males ($P = 0.2428$), but was marginally

correlated for females ($P = 0.0820$). Productivity (number of young fledged per nesting attempt) was negatively correlated, however, with response index for both males and females ($F_{1,18} = 5.68$, $P = 0.0284$, $R = -0.4898$; $F_{1,20} = 4.36$, $P = 0.0497$, $R = -0.4232$; respectively; Figure 5.3). Response index explained a significant proportion of the variation in productivity for both males ($R^2 = 0.2399$) and females ($R^2 = 0.1791$). When failed nests were not included in the analysis, response index explained a larger proportion of the variation in productivity for both males ($R^2 = 0.3270$) and females ($R^2 = 0.2416$). These results indicate that individuals that responded more intensely to overflights experienced lower productivity on average, and the relationship between productivity and response intensity was strongest among those individuals that raised at least one fledgling.

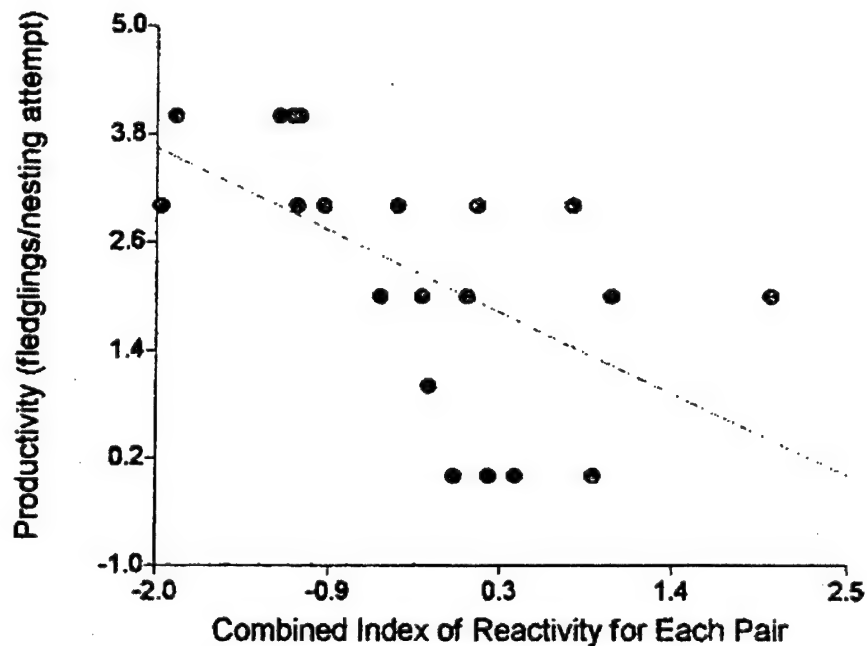


Figure 5.3 Productivity (number of young fledged per nesting attempt) of Peregrine Falcons in relation to intensity of response by mated pairs (see text for calculation method of response index) to low-altitude jet aircraft overflights along the Tanana River, east-central Alaska.

There was a trend toward a positive correlation between the response indices of individuals and their mates (1-way ANOVA, $F_{1,18} = 3.77$, $P = 0.0680$; Figure 5.4).

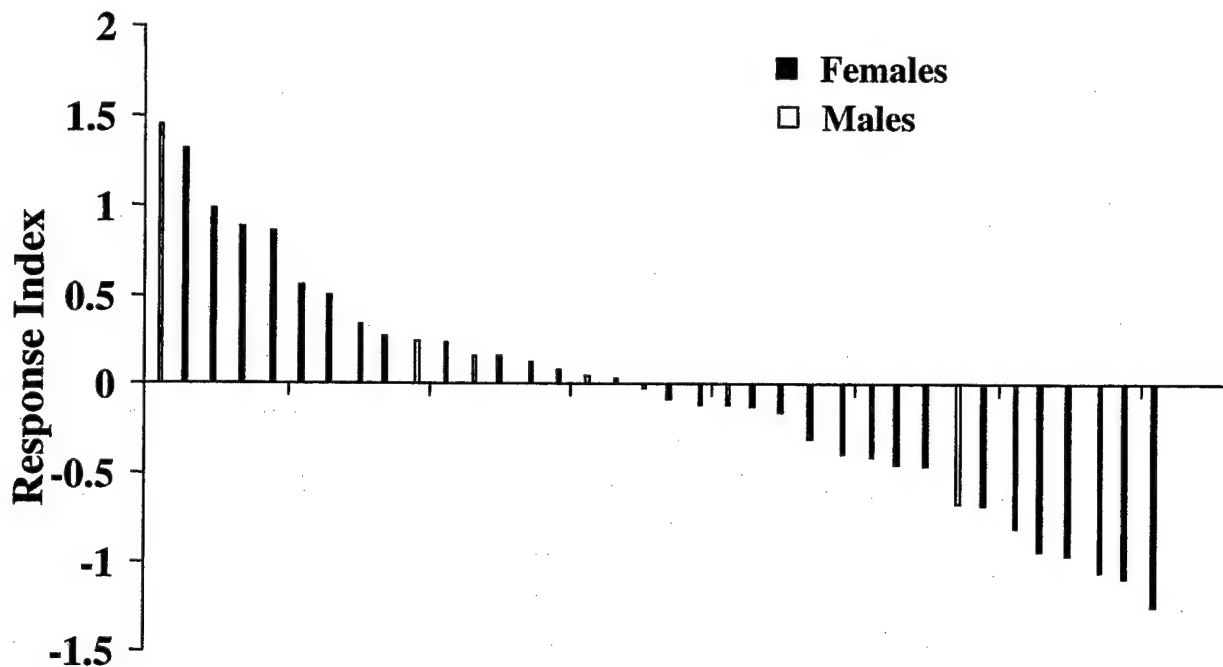


Figure 5.4 Response index of nesting adult Peregrine Falcons (see text for calculation method) to low-altitude jet aircraft overflights within 1,000 m slant distance. A response index of 0 is the average for that sex of nesting adult at that stage of the nesting cycle.

This trend suggests that the members of a pair tended to be similar in response intensity to overflights, rather than compensatory. When the response indices for the two members of a breeding pair were added together, there was a negative correlation between this combined response index of the pair and productivity ($F_{1,18} = 8.66$, $P = 0.0086$, $R^2 = 0.3249$; Figure 5.5). The combined response index did not differ for nests located in the upper stretch compared with those in the lower stretch of the study area (upper stretch: -0.4922 , $n = 11$; lower stretch: -0.0059 , $n = 9$; $F_{1,18} = 1.20$, $P = 0.2880$). Combined response indices for pairs also did not differ between experimental nests (-0.2310 , $SE = 0.2300$, $n = 19$) and reference nests (-1.07 , $n = 1$; $F_{1,18} = 0.66$, $P = 0.4255$); or between nests subjected to many overflights (0.0137 , $SE = 0.2745$, $n = 12$) and those subjected to few overflights (-0.7040 , $SE = 0.2745$, $n = 8$; $F_{1,18} = 2.73$, $P = 0.1156$). The average combined response index of pairs tended to be higher in nests from the high noise category (-0.1399 , $SE = 0.2190$, $n = 18$) compared with those from the low noise category (-1.475 , $SE = 0.6571$, $n = 2$; $F_{1,18} = 3.72$, $P = 0.0698$), but the differences were small.

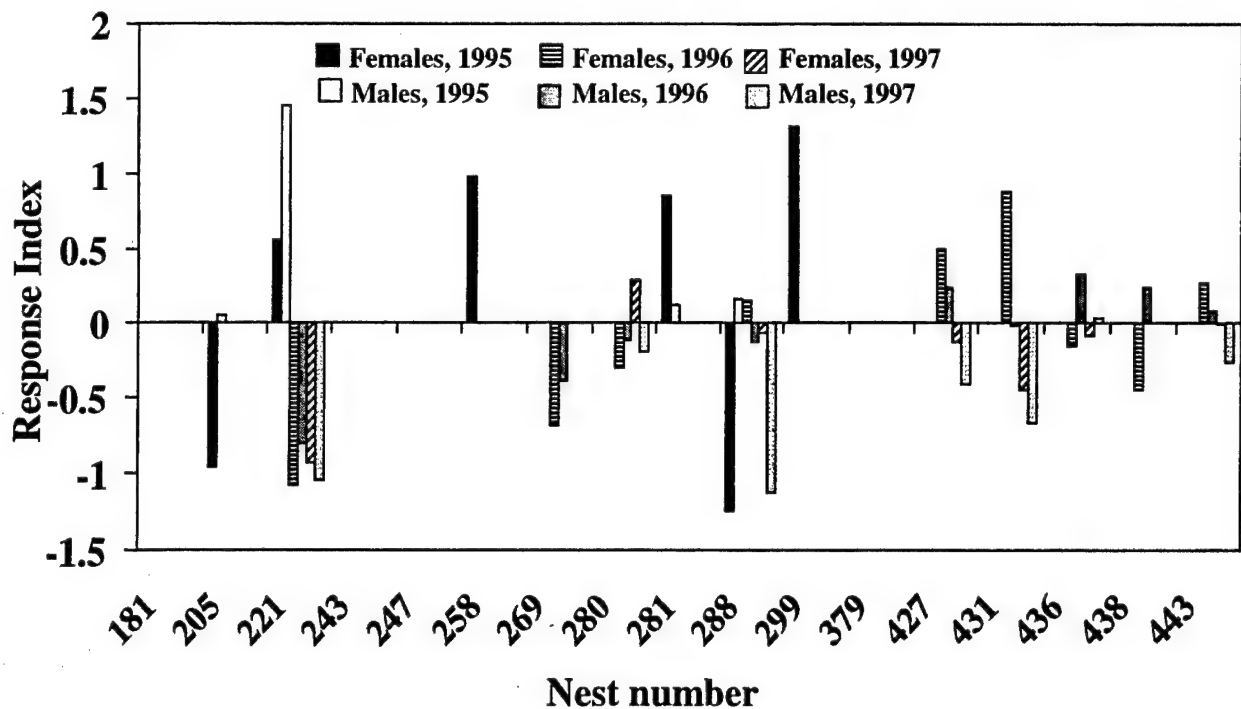


Figure 5.5 Average response index of nesting Peregrine Falcons (see text for calculation method) to low-altitude jet aircraft overflights. Response indices are separated by nest site (identified by nest number in kilometers from the river source), sex, and year. A response index of 0 is the average for that sex of nesting adult at that stage of the nesting cycle.

DISCUSSION

The response indices of individual Peregrine Falcons exposed to low-altitude jet aircraft overflights were negatively correlated with nesting productivity (i.e., the number of young fledged per nesting attempt). This indicates that the greater the magnitude of response by an individual towards overflights, the fewer young it was likely to fledge. This same negative correlation existed between the combined response index of mated pairs and their productivity. Together with the trend toward a positive correlation between the response index of an individual and that of its mate, this indicates that attributes of a breeding pair that were associated with lower productivity were also associated with more intense responses toward overflight disturbance on the part of both members of the breeding pair. The strength of the relationship between response index and productivity was stronger when pairs that failed to raise any young were excluded from the analysis. This suggests that some complete nest failures occurred due to factors unrelated to the association of response index with productivity. Possible factors that caused complete nest failure and were not related to parental behavior include nest predation, landslides, or death of one of the parents.

These results are consistent with the hypothesis that the reduction in productivity of nesting Peregrine Falcons due to overflights is a result of the intensity of behavioral responses. We predicted a negative correlation between response and productivity, assuming that responses represent a measurable cost to current reproductive output. This is consistent with the Awbrey and Bowles (1990) model for predicting the cost of overflight disturbance from the intensity of the response. The alternative hypothesis was not supported, namely that little or no response to jet aircraft overflights reflects a low investment in the current reproductive attempt and a tendency toward reproductive failure.

The response index was calculated as the average residual for response intensity of each individual Peregrine Falcon, based on the gender-specific regression of response intensity on slant distance. The response index for pairs was not greater for those at nests exposed to relatively high doses of overflights, such as experimental or "many overflights" categories. The response index for pairs in the "high noise" category, however, was marginally greater than the "low noise" category, suggesting that lower response indices were not a reflection of habituation to frequent loud overflights.

The apparent lack of an effect of military jet overflights on nesting success was associated with the generally low intensity of response by adult Peregrine Falcons to overflights (see Chapt. 4).

Peregrine Falcons nesting on the lower stretch of the study area had lower nesting success than those nesting on the upper stretch. There were more failed nests on the lower stretch, and successful nests fledged fewer young. This trend continued into 1998, after the field study had terminated and the close, intentional jet aircraft overflights had ended. During the 1998 breeding season, productivity in the upper stretch was 3.30 fledglings per nesting attempt ($sd = 0.95$, $n = 10$, range = 2–4) while in the lower stretch productivity was only 1.83 fledglings per nesting attempt ($sd = 1.60$, $n = 6$, range = 0–4; 1-tailed, 2-sample t test, $P = 0.0405$, $df = 7$; see Chapter 2 of this report). Although the lower stretch of the study area is closer to Eielson AFB, military bombing ranges, the city of Fairbanks, and other human settlements, and thus was exposed to more background noise from jet aircraft and other potential sources of disturbance, there was no apparent relationship between Peregrine Falcon productivity and either number or intensity of overflights in this study. Also, the average response index for pairs in the lower stretch did not differ from that of pairs in the upper stretch.

If disturbance is defined as a stimulus that lowers the probability of successful reproduction, then high doses of jet aircraft overflights apparently did not constitute a significant disturbance to most nesting Peregrine Falcons in this study. Murphy et al. (Chapter 10 of this report) found that nesting success did not differ widely among overflight disturbance categories (low, moderate, or high, as measured by sound exposure levels) for nests along the Tanana River, but nesting success did differ for Peregrine Falcon nests at off-river sites. They reasoned that important differences may exist in habitat quality, sensitivity to disturbance among subpopulations of Peregrine Falcons, or both.

Response to disturbance apparently plays a role in limiting productivity of Peregrine Falcons. Because individual Peregrine Falcons differ in their response intensity to similar jet overflights, the actual dose of jet aircraft noise is apparently not as accurate a measure of disturbance as the response intensity elicited from breeding adults. The amount of disturbance perceived by Peregrine Falcons, as reflected in their response, is a better predictor of effects on nesting success. Additionally, jet aircraft overflights may represent only a fraction of the potential disturbances that nesting Peregrine Falcons are exposed to during the breeding season. The response of breeding Peregrine Falcons to a wide variety of other disturbances may influence productivity as well.

Higher intensity responses could interfere with parental duties, causing lower productivity among pairs that have had little previous exposure to overflights and are thus not habituated. Alternatively, factors other than disturbance may be responsible for low productivity (e.g., young and inexperienced parents, newly established breeding pairs), and these factors could also be associated with higher response intensity to disturbance. Parents with low probability of successfully fledging young may maximize their fitness by behaving in a manner that enhances survival at the expense of investment in raising young. The available data support the hypothesis that factors other than disturbance, such as age and experience, may be related to both low response indices and high productivity. Habituation apparently does not play a prominent role in determining response, as neither response nor productivity differed between experimental versus reference nests or between nests in the "many overflights" category versus the "few overflights" category.

CONCLUSIONS

Productivity of peregrine falcons in the study area was within the normal range for east-central Alaska and the Tanana River. There were no differences in productivity between experimental

versus reference nests (i.e., between nests that were intentionally overflown by jet aircraft versus nests that were not intentionally overflown), between nests exposed to many overflights versus those exposed to few overflights, or between nests exposed to high levels of aircraft noise versus those exposed to low noise levels.

The average magnitude of response to military jet overflights by nesting peregrine falcons was quantified by calculating a response index for each individual nesting adult. Individual peregrine falcons differed in response index to overflights. These differences existed even after controlling for gender differences in response index and variation in the intensity of jet overflights.

Productivity of nesting peregrine falcons was negatively correlated with the response index of individual falcons to jet overflights. Productivity was also negatively correlated with the combined response index of mated pairs. Thus higher intensity of response to jet overflights was associated with lower nesting success for breeding peregrine falcons in our study.

Response indices of individual peregrine falcons or mated pairs did not differ between experimental nests (nests within MTRs) versus reference nests (nests outside MTRs), nor between nests exposed to many overflights versus few overflights, nor between nests in the upper stretch versus in the lower stretch of the river. The average response index of peregrine falcons nesting at sites in the "high noise" category was marginally higher than those in the "low noise" category.

The response intensity of breeding peregrine falcons to low-altitude jet overflights is a better indicator of subsequent productivity than the actual dose (number and intensity) of jet overflights. This is likely a reflection of lower parental investment among peregrine falcon breeding pairs that exhibit high intensity responses. The results of this study might be explained by the tendency of younger, less experienced peregrine falcons to exhibit higher intensity responses to disturbance, and nesting attempts by these breeding pairs are less likely to be successful.

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CHAPTER 6

COMPARISON OF BEHAVIORAL RESPONSES BY NESTING PEREGRINE FALCONS TO SEVERAL TYPES OF POTENTIAL DISTURBANCES

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ABSTRACT

We investigated the relative magnitude of potential disturbances to breeding Peregrine Falcons by observing behavioral responses to disturbance events at nests along the Tanana River, Alaska, during the 1995–1997 breeding seasons. As part of a larger study on the effects of Air Force aircraft overflights, military jets flew over a subsample of nests under observation (experimental nests). Close overflights (< 1000 m slant distance) by military jets accounted for 57% of potential disturbances at experimental nests, but only 2.6% of potential disturbances at reference nests. Other potential disturbances at reference nests included civilian fixed-wing aircraft (41%), boats (33%), avian predators (17%), helicopters (5.1%), and humans and other mammals (1.3%). Peregrine Falcons responded differently to animate and inanimate sources of disturbance; flight responses were a common reaction to animate sources, but not to inanimate ones. Peregrine Falcons responded most intensely and most frequently to other raptors, particularly conspecifics. Forty-two percent of responses to other raptors were flight responses. Humans and other mammals near the nest elicited extremely intense defense responses, but these interactions occurred infrequently. Among inanimate disturbances, Peregrine Falcons responded most intensely to boats and least intensely to helicopters and small fixed-wing aircraft; military jets elicited intermediate responses that were indistinguishable from those to boats and other aircraft. Only 2–6% of responses to close (< 1000 m slant distance) mechanized vehicles were flight responses. Number of flight responses to potential disturbances was not correlated with productivity of the nesting pair. Therefore, quantifying flight responses may not be the most sensitive indicator of the magnitude of anthropogenic disturbance to nesting Peregrine Falcons.

INTRODUCTION

Peregrine Falcons (*Falco peregrinus*) respond strongly to intruders near their nests and have been known to attack a wide variety of potential predators of their eggs and nestlings, as well as inanimate intruders such as fixed-wing aircraft and helicopters (White and Sherrod 1973; Monneret 1974; Cade and White 1976; Olsen and Olsen 1980). Startle and flight responses by Peregrine Falcons have also been observed in response to close overflights by jet aircraft and other loud, sudden noises, such as sonic booms and log truck jake brakes (Manci et al. 1988; Awbrey and Bowles 1990; Ellis et al. 1991; R. Ambrose pers. comm.[1995]; J. Pagel pers. comm.[1997]).

The objective of this study was to examine the role of jet aircraft overflights as a potential disturbance affecting productivity of nesting Peregrine Falcons by measuring the response intensity to other potential sources of disturbance and comparing those responses to responses elicited by jet overflights. We predicted that jet aircraft would elicit more intense responses than helicopters and fixed-wing aircraft, after controlling for slant distance (Awbrey and Bowles 1990). We also predicted that close jet overflights would elicit a greater proportion of intense startle responses than would any other type of potential disturbance.

Bowles et al. (1990) postulated that an increase in raptor flight responses induced by jet aircraft overflights could result in lower productivity. In a study of the relationship between immediate behavioral responses of Peregrine Falcons to jet aircraft overflights and nesting success, we did not find a negative correlation between number of flight responses and productivity, but we only observed a total of eight flight responses induced by jet aircraft overflights, and all were by males (Chapter 5). By including flight responses induced by other potential sources of disturbance, including helicopters, fixed-wing aircraft, boats, thunder, animals, and humans, we sought to increase the sample size and more accurately assess the possible relationship between flight responses and productivity. Additionally, it would be helpful to place potential disturbance caused by jet aircraft overflights in the context of overall disturbance during the breeding season, as well as compare the intensity of response to jet overflights with responses to other sources of disturbance.

Historical research on Peregrine Falcons in Alaska has focused on reproductive parameters and population status (Cade, 1960; White, 1964; Ambrose et al., 1988; Wright and Bente, 1999). This study builds on the earlier work by examining how jet aircraft overflights and other disturbances might affect reproduction and population status.

STUDY AREA

The Peregrine Falcons that were the subjects of this study nested along a 250-km (156-mi) stretch of the Tanana River between Tanacross and Salcha in east-central Alaska (from lat. 63°08'N, long. 143°36'W to lat. 64°18'N, long. 148°45'W; Figure 6.1). The Tanana River is a braided, glacially-fed river in interior Alaska. The valley floor is covered in boreal forest of predominately white spruce (*Picea glauca*), black spruce (*P. mariana*), paper birch (*Betula papyrifera*), and quaking aspen (*Populus tremuloides*), with many boggy areas and small thaw lakes. The northern bank of the Tanana River is intermittently bounded by schist and granite cliffs ranging in height up to several hundred meters. These cliffs are where Peregrine Falcons most frequently locate

their nests. Some occupied cliffs overlook wide, braided areas of the river, while others are located near lakes, ponds, marshes, or other expanses suitable for hunting.

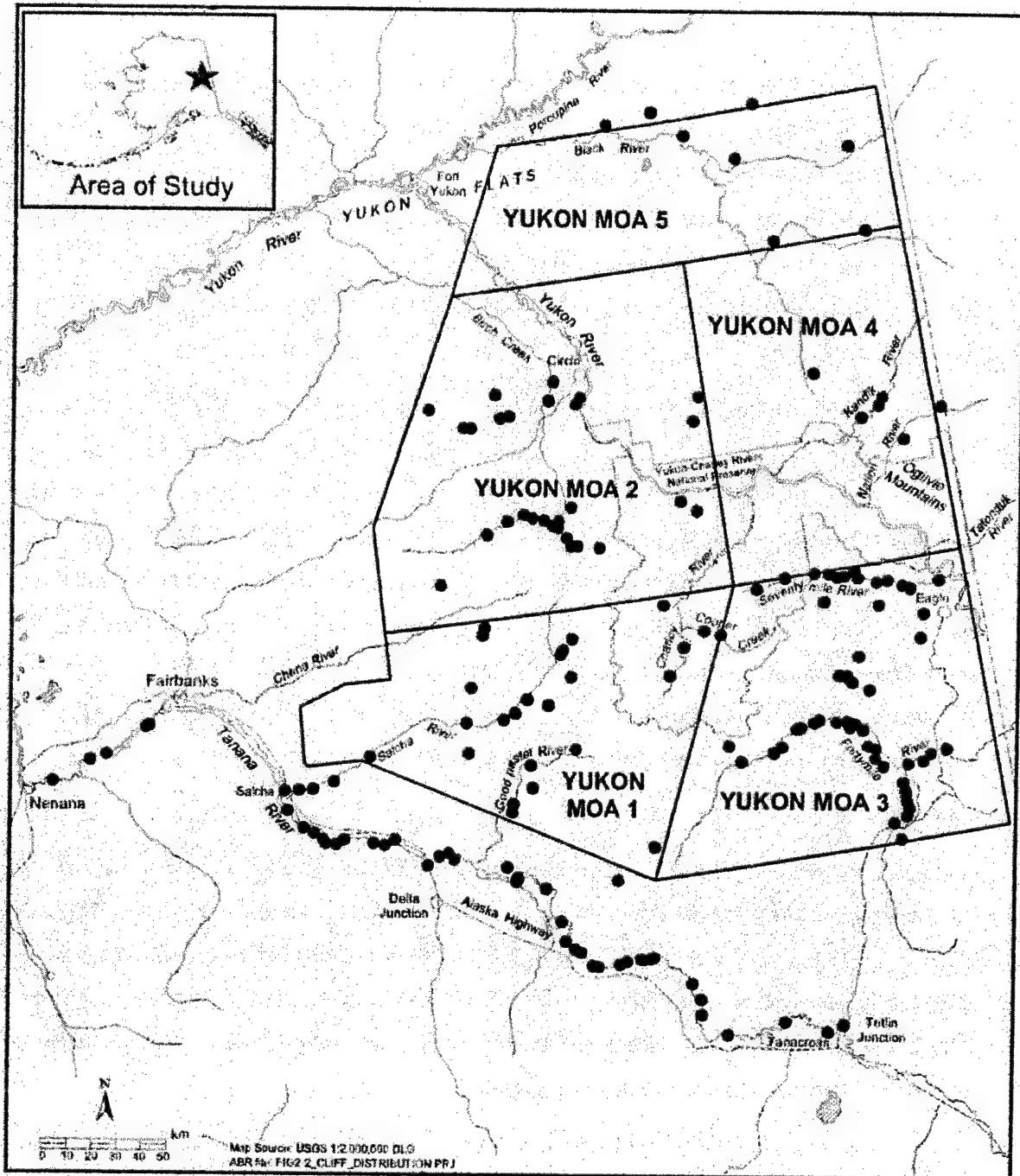


Figure 6.1 Study area along a 250-km stretch of the Tanana River between Tanacross and Salcha, east-central Alaska.

Field observations were conducted during the breeding seasons of 1995, 1996, and 1997 and were initiated after ice break-up on the river allowed access to active nests by riverboats (early May). Observations continued until the young had fledged and left the area of the nest (late August/early September).

Approximately half of the Peregrine Falcons under observation nested in Military Training Routes (MTRs), which are air corridors where low-altitude training flights by military jet aircraft can be conducted. Three MTRs extend across the study section of the Tanana River (Figure 6.1); nests within MTRs are referred to as experimental. Nests outside MTRs, where jets were subject to altitude restrictions, are considered reference nests. Nests were identified by river kilometer, with kilometer zero (0) at the source of the Tanana River (confluence of Nabesna and Chisana rivers).

During the 1995 field season, we recorded observations at five experimental nests and six reference nests. All of these nests were located along the Tanana River between Tanacross (km 155) and Sawmill Landing (km 305) (hereafter the "upper stretch"). In 1996 and 1997, the study area was expanded to include another stretch of the river between Delta Junction (km 385) and Salcha (km 472) (hereafter the "lower stretch"). We observed nine experimental nests and three reference nests in both 1996 and 1997. Six of these nests were located in the upper stretch of the study area, and six were located in the lower stretch.

We selected nests for observation based on access to observation sites opposite cliffs and visibility of the nest ledge from the observation sites.

METHODS

Field crews conducted behavioral observations of breeding Peregrine Falcons and collected data on characteristics of potential disturbances. Two field crews were present in the study area in all three years. Field crews accessed the various nests using river boats (21-foot or 24-foot Alwelds with 150-hp jet outboards). We made observations from across at least one channel of the river, between 300 and 750 m from each nest. Observation distance also depended on the sensitivity of each pair of Peregrine Falcons to observer presence.

Behavioral observations were divided into the four phases of the nesting cycle: (1) pre-incubation (including arrival of breeding adults at the nest site, courtship, and egg-laying); (2) incubation of eggs; (3) rearing of young (including hatching); and (4) fledging (from the first observed flight by a nestling until all fledglings had left the nest area). In addition, we treated failed nests as a separate phase of the nesting cycle for purposes of data analysis. Most data were collected during

the incubation, nestling-rearing, and fledging phases because nests were usually inaccessible before ice break-up on the Tanana River, which occurs around the peak of egg-laying.

We observed behavioral responses of Peregrine Falcons to potential disturbances with the aid of 10x binoculars, 15-45x spotting scopes, and Questar telescopes. We also recorded responses using two Canon L2 Hi-8 mm video cameras, each equipped with a 250-mm telephoto lens and a 2X teleconverter. These cameras recorded continuously during observation periods in order to have a video record of responses to potential disturbances. Each camera was mounted on a tripod and powered by a 12V deep-cycle battery with a DC-S10 12V adapter. The cameras used Hi-8 mm videotapes, which record for up to 2 hours. One video camera was focused on the nest ledge during observation periods. We focused the second camera on whichever adult was not at the nest ledge during the incubation and nestling-rearing periods. If both adults were in sight, but away from the nest ledge, we focused the second camera on the female. Late in the fledging period, when the nest ledge was rarely occupied, cameras were focused on the two birds (or groups of birds) that were most easily viewed.

We recorded responses to disturbance as one of the following categories: unknown response, no response, attentive, alert/alarmed, flight intention movement, stand up, crouch/cower, unknown flying, defensive flying, or evasive flying. Detailed definitions of these response categories are provided in Chapter 5. Briefly, no response was considered response intensity 0, attentive was response intensity 1, alert/alarmed was intensity 2, flight intention movement and stand up were intensity 3, crouch/cower was intensity 4, unknown flying was intensity 5, defensive flying was intensity 6, and evasive flying was intensity 7.

Response intensities 0 and 1 were classified as "minimal" responses, while response intensity 2 was an "intermediate" response. Response intensities 3 and 4 were classified as "intense" responses, and response intensities 5, 6, and 7 were classified as "flight" responses. Regardless of the type of potentially disturbing stimulus that occurred, behavioral responses to potential disturbances were classified in the same way.

Military jet overflights of nests in the MTRs were coordinated with existing missions of the 11th Air Force from Eielson and Elmendorf Air Forces Bases, Alaska. Air Force personnel (Forward Air Controllers, or FACs) were present in the field during much of the 1996 and 1997 field seasons to direct military jet overflights and help with data collection. Type III Standard and Compact Animal Noise Monitors (ANMs; Hill 1995; Kugler 1996) were deployed near the nests for the duration of the breeding season and were used for monitoring noise levels during jet overflights.

For overflights by jets, helicopters, or fixed-wing aircraft, we recorded the type of aircraft, altitude of the aircraft above the nest (usually estimated, sometimes obtained directly from pilots), and estimated lateral distance of the aircraft from the nest. Slant distances were calculated for each overflight from estimates of altitude and lateral distance. Close jet overflights, defined as < 1000 m slant distance from a nest, were used to examine the effects of jet overflight parameters on behavior of Peregrine Falcons (Chapter 5). Accordingly, responses of breeding Peregrine Falcons to other close (< 1000 m slant distance) potential disturbances (helicopters, fixed-wing aircraft, boats, and animal intruders) were compared with responses to close overflights by jet aircraft. For all other disturbances (thunder, gunshots, highway noise, sonic booms), slant distance was not an appropriate measure of intensity, and the ANMs did not record these types of noise events. Comparison with these other types of potential disturbance is problematic because of a lack of quantifiable data to use as criteria for intensity (i.e., closeness, loudness). Therefore, we provide descriptions of the intensity of response to these noises without including them in statistical analyses of response intensity.

Statistical Analysis

Graphical displays were used for preliminary examination of the data. We used the NCSS97 statistical package (Hintze 1997) to perform statistical analyses, including descriptive statistics for means, standard deviations, and ranges; regression analyses; two sample t-tests; Mantel-Haenszel tests; one-way ANOVAs; and Duncan's multiple comparison tests. We used multiple regression to explore the relationship between type of disturbance (jets, helicopters, fixed-wing aircraft, boats, birds, mammals, and people) and intensity of Peregrine Falcon response. We assumed that potential disturbances that did not elicit more than minimal responses were not likely to constitute actual disturbances (i.e., have a detrimental effect on productivity).

We chose slant distance as the primary selection criterion for inclusion of overflights in the response analysis because slant distance explained a significant proportion of the variation in Peregrine Falcon response to jet aircraft overflights (Chapter 5). Also, we lacked noise measurements for most noise events that were not due to military jet overflights.

RESULTS

Inanimate Potential Disturbances

A total of 878 above-threshold ANM measurements were recorded during the three years of the study, but only four noise events (0.5%) were known to have resulted from boats, helicopters, or small fixed-wing aircraft. A total of 676 close (< 1000 m slant distance) aircraft overflights and other inanimate potential disturbances occurred when breeding Peregrine Falcons were visible to

observers during the course of the 3-year study. Inanimate potential disturbances were caused by military jet aircraft (393 events, 58% of close inanimate potential disturbances), helicopters (34 events, 5%), large military fixed-wing aircraft (6 events, 1%), small civilian fixed-wing aircraft (142 events, 21%), and motorboats (100 events, 15%; Figure 6.2).

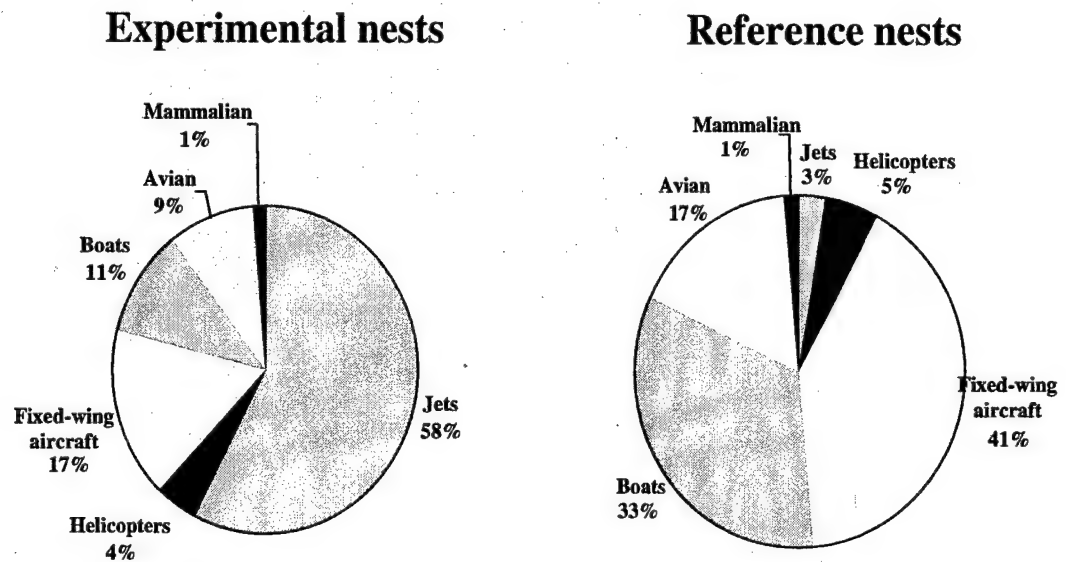


Figure 6.2 The proportion of each type of close (< 1000 m slant distance) potential disturbance observed for nesting Peregrine Falcons during the 1995-1997 breeding seasons along the Tanana River, Alaska.

Animate Potential Disturbances

Only 83 (11%) of all potential disturbances during observation periods were not noise-producing, but were instead due to natural nest predators (Figure 6.2). The most frequently observed disturbance from potential nest predators was caused by other birds (87%, 72 instances). Birds accounted for 10% of total potential disturbance events. The relative frequency of potential disturbances by each bird species observed is presented in Figure 6.3.

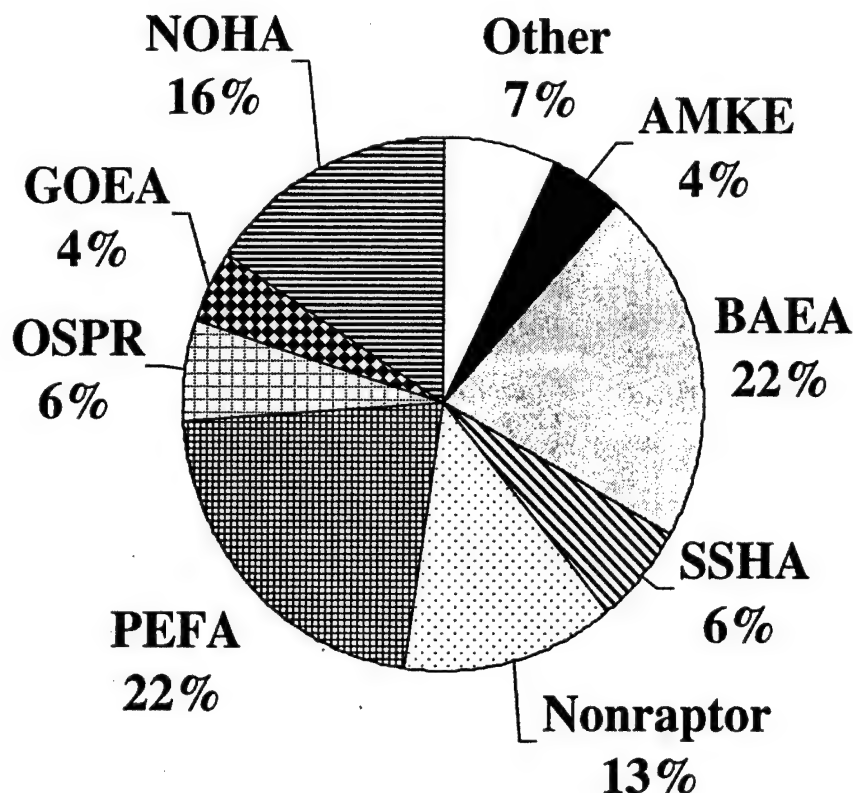


Figure 6.3 The proportion of each species of avian nest predator ($n=72$) observed within 1000 m of Peregrine Falcon nests during the 1995-1997 breeding seasons along the Tanana River, Alaska. Species included: AMKE (American kestrel, *Falco sparverius*), BAEA (Bald Eagle, *Haliaeetus leucocephalus*), SSHA (sharp-shinned hawk, *Accipiter striatus*), RLHA (rough-legged hawk, *Buteo lagopus*), PEFA (Peregrine Falcon, *Falco peregrinus*), OSPR (osprey, *Pandion haliaetus*), RTHA (red-tailed hawk, *Buteo jamaicensis*), GOEA (golden eagle, *Aquila chrysaetos*), NOHA (northern harrier, *Circus cyaneus*), HEGU (herring gull, *Larus argentatus*), CORA (common raven, *Corvus corax*), and other (1 each goshawk [*Accipiter gentilis*], gyrfalcon [*Falco rusticolus*], and unidentified).

Other Peregrine Falcons and Bald Eagles (*Haliaeetus leucocephalus*) were the most frequent species of avian intruder observed near active Peregrine Falcon nests. Mammalian predators accounted for only 4% (3 instances) of all animate potential disturbances recorded during observation sessions. Potentially disturbing human intrusions, exclusive of researcher activities, were observed only twice, once at each of two different nests.

Non-visual Potential Noise Disturbances

Non-visual potential noise disturbances, such as thunder, gunshots, highway noise, and sonic booms, were not recorded by the ANMs. Observers did, however, record the times of each potentially-disturbing noise event, as well as the response of any visible Peregrine Falcons to the

noise event. We recorded 52 instances of non-visual noise events when Peregrine Falcons were visible to observers (compared to 83 animate and 676 inanimate potential disturbances). Only minimal responses (no response or attentive) were elicited by thunder, road noises, or sonic booms (all were quite distant). One episode of gunshots (at least 1 km [.62 mi] away) elicited a flight response by a female, and another instance of gunfire elicited an alert response.

Peregrine Falcon Responses to Inanimate Potential Disturbances

A total of 40% of all known responses by Peregrine Falcons to potential inanimate disturbances were listed as "no response." An additional 51% were categorized as attentive, suggesting that the adult falcons were aware of the noise but not disturbed. Alert responses accounted for 5% of all known responses to potential inanimate disturbances; 98% of these alert responses were induced by military jet overflights. Less than 1% of all known responses to potential inanimate disturbances were classified as intense (stand, crouch/cower, flight intention movement); all intense responses to inanimate potential disturbances were induced by military jet overflights. Only 3% of responses to inanimate disturbances were classified as flight responses; 35% of these were due to military jet overflights.

Peregrine Falcons responded differently to different types of inanimate disturbance, even after accounting for slant distance (1-way ANOVA; female, $F_{3,428} = 5.75$, $P = 0.0007$; male, $F_{3,334} = 5.31$, $P = 0.0014$). Only minimal responses (no response or attentive) were elicited by large fixed-wing aircraft. All but one alert response was due to military jet aircraft overflights. Flight responses were induced by boats (41%, 9 responses), military jets (36%, 8 responses), small fixed-wing aircraft (18%, 4 responses), and helicopters (5%, 1 response) (Figure 6.4). Mean response intensity of females was significantly higher for motor boats than for either helicopters or fixed-wing aircraft. The mean response intensity of female Peregrine Falcons towards military jets did not differ from that towards boats or other types of aircraft (Duncan's Multiple-Comparison Test, $P < 0.05$). Male Peregrine Falcons, on the other hand, responded with similar intensities to all types of inanimate potential disturbance (Duncan's Multiple-Comparison Test, $P > 0.05$).

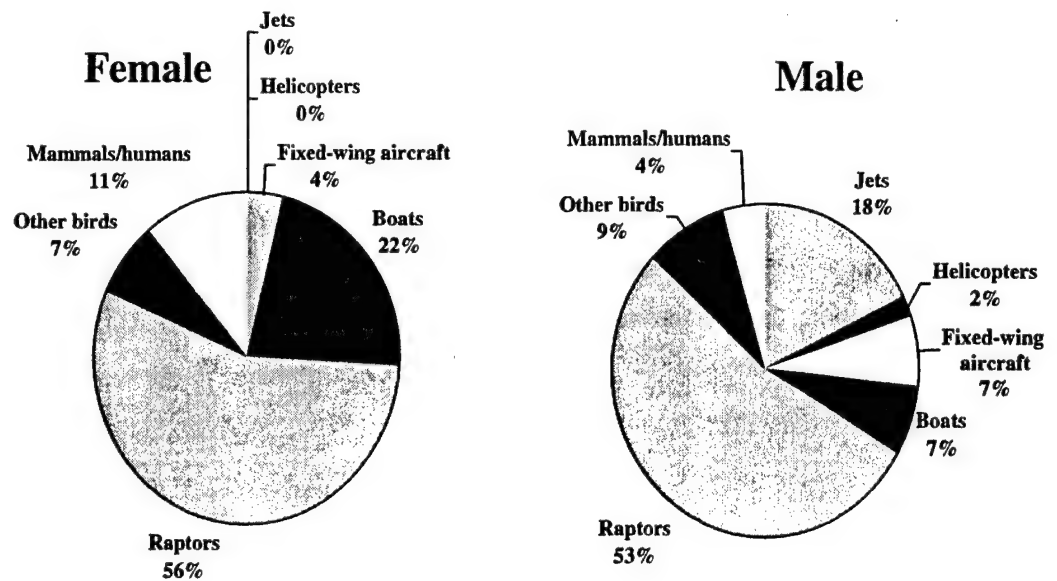


Figure 6.4 The proportion of total flight reactions observed for nesting female ($n = 29$) and male ($n = 44$) Peregrine Falcons in response to each type of close (< 1000 m slant distance) potential disturbance during the 1995-1997 breeding seasons along the Tanana River, Alaska.

Peregrine Falcon Responses to Animate Potential Disturbances

A total of 27% of all known responses to animate potential disturbances (natural predators) were recorded as “no response.” An additional 31% were categorized as attentive, suggesting that the Peregrine Falcons were aware of the presence of the intruder, but were not disturbed. Alert responses accounted for 3% of all known responses to animate intruders, and 1% of all known responses to animate intruders were classified as intense (stand, crouch/cower, flight intention movement). A total of 37.5% (50) of known responses to animate intruders were classified as flight responses (Figure 6.3), a much higher incidence of flight responses than for any other category of potential disturbance.

Peregrine Falcons responded differently to the proximity of different types of potential predators. Responses were most intense to other raptors within 500 m of the nest (Figure 6.4). A total of 42% of all responses to other raptors were flight responses. Peregrine Falcons responded nearly as intensely to humans near their nests (31% of responses were flight responses), followed by potential avian nest predators other than raptors (25% flight responses).

We witnessed only three interactions between nesting Peregrine Falcons and mammals near the nest: mink (*Mustela vison*), black bear (*Ursus americanus*), and red fox (*Vulpes vulpes*). In all three of these encounters, only the female was involved and reactions ranged from no response to defensive flight. One of these instances, which we recorded on videotape, involved a mink that came into the nest after nestling while it was being brooded by the female. The female responded violently, flying off the nest scrape and knocking the mink off the nest ledge at the same time. We also observed a black bear with two cubs and a fox near active nests. The female falcon responded violently to the bear and cubs, flying off the nest scrape, vocalizing, diving and attacking, and pulling out tufts of fur until the intruders left the area. The red fox was on an outcropping above the nest ledge and elicited no response from the attendant female falcon, apparently because the fox was undetected.

Comparison of Peregrine Falcon Responses Among Types of Potential Disturbance

Individual Peregrine Falcons responded differently to different types of close (< 1000 m slant distance from the nest) potential disturbance (1-way ANOVA, females: $F_{5,489} = 19.65$, $P < 0.00001$; males: $F_{4,390} = 30.13$, $P < 0.00001$, respectively; Figure 6.5). Response intensity of both male and female Peregrine Falcons was significantly higher towards potential avian predators than towards inanimate potential disturbances (Duncan's Multiple-Comparison Test, $P < 0.05$). Males responded with similar intensities to all animate potential disturbances (Duncan's Multiple-Comparison Test, $P > 0.05$). Unlike males, however, females exhibited significantly lower mean response intensities against non-raptor avian species in comparison to other raptors and mammalian predators (Duncan's Multiple-Comparison, $P < 0.05$).

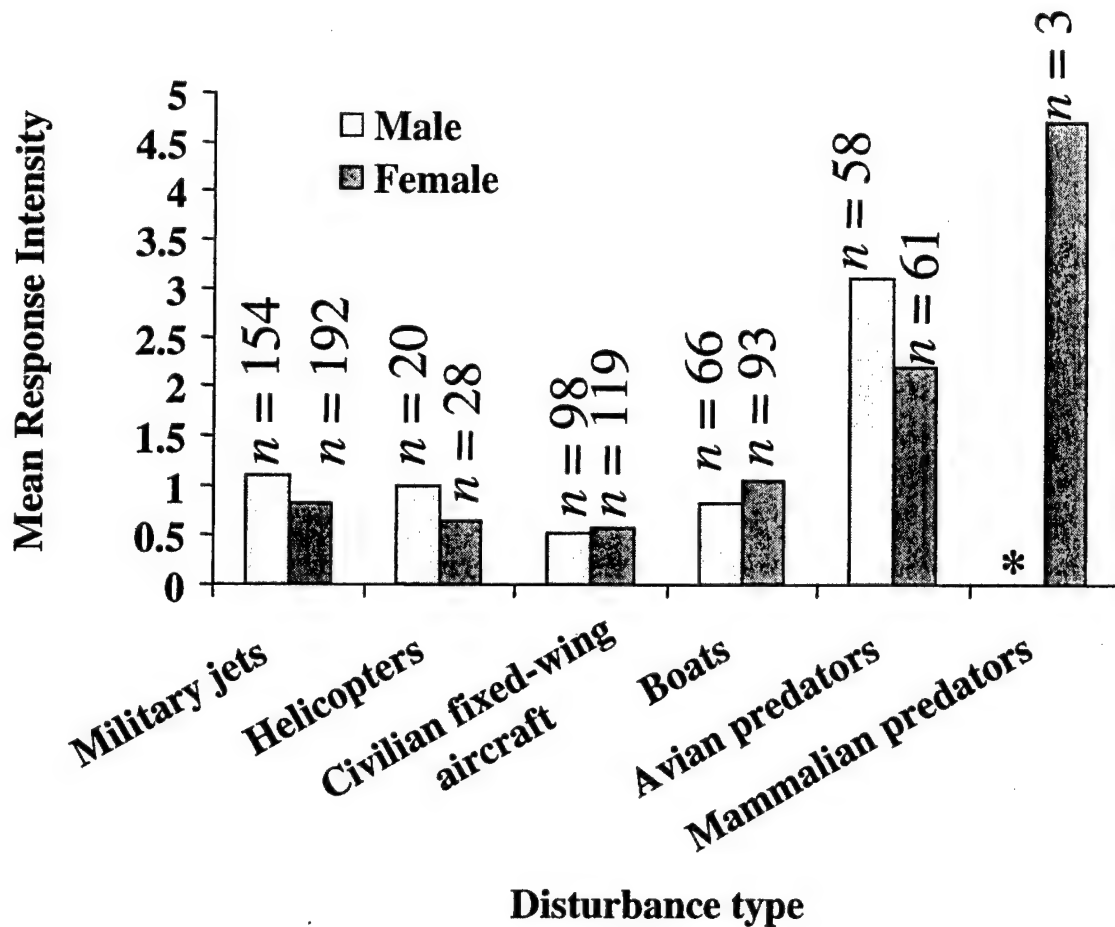


Figure 6.5. Mean reaction intensity of Peregrine Falcons, separately by sex, to each type of close (slant distance < 1000 m from the nest) potential disturbance (military jets, civilian fixed-wing aircraft, helicopters, boats, avian intruders, and mammals).

Relationship Between Flight Responses and Productivity

None of our measures of Peregrine Falcon nesting success (hatch date, nestling survival, productivity) was related to the proportion of flight responses to all known responses to close potential disturbances (by males, by females, or pairs combined; Table 6.1).

Table 6.1. *Peregrine Falcon nesting success and productivity in relation to flight responses (proportion of all responses observed by males, females, or pairs) to all types of close (< 1000 m slant distance) potential disturbances.*

Flight response	Hatch date	Nestling survival	Overall productivity
Male flight responses	F1,30 = 0.9050, P = 0.3490	F1,27 = 0.8409, P = 0.3673	$F_{1,32} = 1.67$, P = 0.2054
Female flight responses	F1,29 = 0.9953, P = 0.3267	F1,26 = 0.7384, P = 0.3980	F1,32 = 0.0963, P = 0.7584
Total flight responses per nesting pair	F1,30 = 1.33, P = 0.2577	F1,27 = 1.42, P = 0.2443	F1,32 = 0.9409, P = 0.3393

DISCUSSION

Several previous studies on behavioral responses of raptors to disturbance have shown that raptors are more sensitive to humans on foot and other raptors near their nests than they are to potential disturbances by machinery (White and Sherrod 1973; Johnson 1988; Grubb et al. 1992). The results of this study agree with these previous studies. Perhaps Peregrine Falcons do not always perceive boats, aircraft, and other vehicles as potential predators. Additionally, visual cues may influence raptors more than noise stimuli (Delaney et al. 1997; Trimper et al. 1998). Peregrine Falcons have extremely acute eyesight and are highly dependent on visual cues for prey detection and capture (Monneret 1978).

Ward and Stehn (1989) determined that geese were more sensitive to helicopter overflights than to overflights by fixed-wing aircraft; Grubb and Bowerman (1997) observed similar results for Bald Eagles. White and Sherrod (1973), on the other hand, noticed that raptor attacks were more frequent on fixed-wing aircraft than on helicopters. Slow-moving potential disturbances (like helicopters) could be more harmful, or at least cause more intense behavioral responses, than higher velocity ones. Owens (1977) found that slow, noisy aircraft, especially helicopters, caused intense behavioral responses in geese. Slower airspeed may enhance the visual stimulus associated with an overflight and thus elicit a more intense behavioral response (Trimper et al. 1998).

Among mechanized potential disturbances, we found that boats induced a higher mean intensity of response in female peregrines than did fixed-wing aircraft or helicopters. Ritchie (1987) found similar results with Peregrine Falcons nesting along the Trans-Alaska Pipeline System. Stalmaster

and Kaiser (1997) obtained similar results when studying the effects of military activity on Bald Eagles. Olsen and Olsen (1980) found that high-speed boats elicited little response from Peregrine Falcons, whereas fishermen caused more intense responses because fishermen tended to move through the nest area slowly and were often directly beneath nests. The close boats observed in our study area were always located in the river channel directly under the nests, and the Peregrine Falcons along the Tanana River may also associate boats with biologists who come to the nest to band young (R. Ritchie, pers. comm.). Stalmaster and Kaiser (1997) also found that Bald Eagles responded more to boats, and less intensely to noise stimuli that were unaccompanied by visual stimuli.

We found a clear gender difference in response intensity among different types of potential disturbances. In general, males responded more intensely than did females, but males also did not appear to distinguish types of disturbance beyond the broad categories of animate and inanimate. Females, on the other hand, seemed to reserve their most intense responses for other raptors and mammalian predators, as opposed to gulls and ravens, and for boats, as opposed to aircraft. Because gulls and ravens are opportunistic nest predators (i.e., are a threat only when the nest is not being attended) and aircraft are not associated with visits to the nest, perhaps the benefit from helping the male defend the nest from these types of threats does not outweigh the cost of leaving the nest and exposing eggs or young. Females may assist their mate in defending the nest only when they perceive an imminent threat of attack on the nest.

CONCLUSIONS

Adult peregrine falcons responded differently to animate and inanimate potential disturbances. Both male and female peregrine falcons responded more intensely to natural nest predators and human intruders than to inanimate potential disturbances (including motor boats, helicopters, fixed wing aircraft, and military jets). Peregrine falcons flew more often in response to potential avian predators (e.g., bald eagles, northern harriers, other peregrine falcons) near the nest site than to any other type of potential disturbance. Nesting peregrine falcons appeared to respond most intensely to potential mammalian predators near the nest, but these events occurred infrequently and could not be compared statistically with response intensity to potential avian predators.

Among inanimate potential disturbances, peregrine falcons responded most intensely to motor boats and least intensely to helicopters and fixed-wing aircraft. They responded with similar intensity to military jets as they did to either boats or other aircraft. Peregrine falcons responded only minimally to unseen noises (except gunshots). Responses to loud sonic booms were not

observed in this study. Peregrine falcons rarely responded to inanimate potential disturbances by flying; consequently, flight responses may not be the best measure of disturbance from inanimate objects, such as military jets. Productivity of nesting peregrine falcons was not correlated with the tendency of the pair to respond to potential disturbances by taking flight (i.e., the proportion of potential disturbances that elicited flight responses). These results suggest that intense responses by the nesting pair to potential avian and mammalian predators near the nest are not associated with lower nesting success.

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CHAPTER 7

FACTORS INFLUENCING NEST ATTENDANCE AND TIME-ACTIVITY BUDGETS OF PEREGRINE FALCONS IN EAST-CENTRAL ALASKA

Angela G. Palmer, Dana L. Nordmeyer Elmore, & Daniel D. Roby

ABSTRACT

An essential prerequisite to examining the impacts of anthropogenic disturbance on avian nesting activities is understanding intrinsic and extrinsic factors that influence allocation of time to breeding behaviors. We examined factors influencing nest attendance and time-activity budgets of Peregrine Falcons (*Falco peregrinus anatum*) breeding along the Tanana River in Alaska in 1995, 1996, and 1997. First, as is typical of most bird species with nidicolous young and biparental care, females attended the nest more than males, and female attendance decreased with progression of the nesting cycle to levels similar to males. Second, nest area attendance followed a circadian rhythm; parents attended the nest area less during early morning and late evening, a prime hunting period, compared to late morning. Finally, although females typically performed most of the incubating, the division of labor between males and females during incubation differed among pairs. Higher attendance in the nest area by females during incubation appeared to be associated with more young fledged among successful pairs.

INTRODUCTION

In nidicolous bird species, a parent's time is mainly partitioned between attending the nest site and foraging for food away from the nest area. Most behaviors performed in the nest area, such as incubating and brooding, are associated with relatively low metabolic costs, or low activity levels (Goldstein, 1988). Adults attending the nest also defend young against predators and provide shelter from severe weather. The major cost to adults of nest attendance is lost foraging time, whereas the major cost to adults of foraging away from the nest area is the increased exposure of eggs and young to potential nest predation. The optimal allocation of time and energy by parents to nest attendance versus foraging influences overall reproductive success (King, 1974; Nur, 1987), a key component of reproductive fitness.

Allocation of time and energy to various activities is dependent on both intrinsic and extrinsic factors. Intrinsic factors include age, hunting skills, and physiological condition of both members

of a breeding pair (Rijnsdorp et al., 1981; Deerenberg et al., 1995; Marzluff et al., 1997). Extrinsic factors may include time of day, weather conditions, presence of potential nest predators, prey abundance, quality of territory, and human-related disturbance (Platt, 1975; Ritchie, 1987; Masman et al., 1988; Steidl, 1995). Different activities require different rates of energy expenditure (Gessaman, 1987; Goldstein, 1988), and disturbance to a breeding pair may lead to increased energy demands, reduced hunting efficiency, or suboptimal allocation of time to nest attendance and foraging. It is essential to understand the underlying intrinsic and extrinsic factors that influence the time-activity budgets of nesting birds prior to examining the impacts of potential disturbance factors on breeding behavior.

As part of a larger study of the effects of disturbance on reproduction and nesting behavior in Peregrine Falcons, we examined factors influencing nest attendance and time-activity budgets of breeding adults in Interior Alaska. Historical research on Peregrine Falcons in Alaska has focused on reproductive parameters and population status (Cade, 1960; White, 1969; Ambrose et al., 1988; Wright and Bente, 1999). Additionally, Ritchie (1987) investigated Peregrine behavior on the Sagavanirktok River, Alaska in response to disturbances; however, sample sizes were small. In this study we had a larger sample size. We investigated differences in parental attendance at the nest as a function of nesting stage, gender, time of day, weather, and nesting pair. In addition, we studied variation in time-activity budgets associated with nesting stage and gender.

We posed several hypotheses regarding nest attendance and time-activity budgets in breeding Peregrine Falcons. First, because of changing requirements for parental care by eggs and chicks as they develop, we expected shifts in parental attendance and time-activity budgets over the course of the breeding cycle, and between genders. Second, parental nest attendance should exhibit circadian patterns and be influenced by abiotic factors, such as weather. We expected attendance to be lower towards dawn and dusk, prime hunting times when the avian prey of Peregrines are more active (Armstrong, 1954). Furthermore, we expected higher attendance during more inclement weather when maintenance energy costs of young are higher (Buttemer et al., 1986), prey are less active, and energetic costs of hunting are likely higher. Finally, we predicted that individual pairs might differ in how the sexes allocated time to nest attendance and other reproductive tasks. Differences among pairs in nest attendance and time-activity budgets may be related to reproductive parameters like the number of young fledged per nesting attempt.

METHODS

Study Area

The study area encompassed a 250-km stretch of the Tanana River between Tok and Fairbanks (from 63° 8' N, 143° 36' W to 64° 18' N, 148° 45' W). In 1995 the study area extended from Tanacross to Sawmill, an approximately 110-km stretch of river. Thirteen active Peregrine Falcon nest sites were found along this stretch of the river. Of these, we selected 10 for observation. In 1996 and 1997, we included an additional 65-km section of the river from Delta to Salcha. A total of 19 and 21 active nests were found in 1996 and 1997, respectively, along both stretches of river. In both 1996 and 1997, we observed six nests in the upper stretch and five nests in the lower stretch. Nests were situated on bluffs overlooking the river. We selected nests for observation based on access to observation sites opposite cliffs and visibility of the nest ledge from the observation sites. Observations were initiated each year as soon as it was safe to travel on the river after ice break-up in mid-May, and continued until the young had fledged and left the nest area (late August/early September). A crew of two to four observers recorded data at each Peregrine Falcon nest and two separate crews were in the field throughout each season. We observed the behavior of adults and nestlings from 300 m away from nests and across at least one channel of river.

Nest Attendance and Time-activity Budgets

We made observations with the aid of binoculars, 15-60 X spotting scopes, and 90 X Questar® telescopes. During incubation, two observers recorded data on nest attendance and time-activity budgets. In 1995, two observers recorded data during the nestling-rearing period; in 1996 and 1997 the number of observers was increased to three during nestling-rearing. There were four observers during the post-fledging stage of the nesting cycle when young were not restricted to the nest ledge. The number of chicks fledged per nesting attempt was recorded at each nest site.

We used the instantaneous scan method to sample activity (Altmann, 1974; Tacha et al., 1985) at one-minute intervals for each parent. Scans contributed data to both nest attendance and time-activity budgets. For nest attendance, we distinguished between attendance at the nest ledge or scrape, attendance in the nest area (within 200 m of the nest ledge), and away from the nest area (greater than 200 m from the nest ledge or scrape or not observed within the nest area). For time-activity budgets, we recorded adult activity as one of the 16 mutually exclusive primary activities listed in Table 7.1. For analysis we lumped primary activities into 6 categories (Table 7.1).

Incubation, brooding, and shading activities were combined because they involve thermoregulation of eggs or young. Perching, feeding self, feeding young, flying, and unknown

were the other activity categories used in analyses. We categorized birds as out of sight (OS1 or OS2--see Table 7.1) for no longer than five minutes after they were last seen. Adults were classified as "unknown", or away from the nest area if they were not seen again within 5 minutes.

Table 7.1. *Activity categories for time-activity budgets of Peregrine Falcons breeding along the Tanana River, Alaska.*

Activity Categories ^a	Primary Activities
Incubating/ Brooding/ Shading	<u>incubating</u> : prone posture covering eggs <u>out of sight (OS1)</u> : on the nest ledge/scrape, but out of sight, e.g., in a cavity at the nest ledge <u>brooding</u> : covering nestlings, wing may be slightly off to the side <u>shading young</u> : shielding nestlings from direct sunlight
Perching	<u>perching</u> : standing on one or both feet within 200 m of nest sight. <u>out of sight (OS2)</u> : known to be on nest cliff, but out of sight, e.g, obscured by vegetation or rock outcrop; adults were classified as unknown if their location was not verified after five minutes.
Feeding Self	<u>feeding self</u> : consuming prey
Feeding Young	<u>feeding young</u> : feeding prey to nestlings or known to be feeding young but out of view, possibly in a cavity
Flying	All flight behaviors: <u>flapping</u> : active flight that involves wing flapping <u>soaring or gliding</u> : passive flight with little to no wing movement <u>stooping</u> : wings tucked, in downward pursuit of prey from altitude <u>diving</u> : Aggressive attack on prey or predator
Unknown	<u>location unknown</u> : assumed to be away from the nest site in flight foraging or perching

^a Other behaviors (lying: with sternum resting on the ground, walking, and running) occurred less than 1 % of time.

We collected observations during three stages of the Peregrine Falcon nesting cycle: incubation, nestling-rearing, and post-fledging. The duration of other stages (courtship and pre-laying, laying, and hatching) is comparatively short, and sample sizes during these stages were correspondingly small. Of the 10 nests observed in 1995, we observed five during incubation, nine during nestling-rearing, and four during post-fledging. One nest was observed during all three stages. In 1996, we sampled behavior during incubation, nestling-rearing, and post-fledging

at 7 of 11 nests. The other four nests were not sampled during each of the three stages because two nests failed following incubation and were replaced by two other nests initiated by different pairs. In 1997, we sampled behavior during all three stages from 9 of 11 nests; of the remaining nests one failed after incubation and was replaced by another pair's nest during nestling-rearing. For analysis, the nestling-rearing phase was further subdivided into three stages, early nestling-rearing (0-10 days post-hatch), mid nestling-rearing (11-24 days), and late nestling-rearing (25-42 days). Consequently, we conducted analyses on five stages of the nesting cycle: incubation; early, mid, and late nestling-rearing; and post-fledging. Stage of the nestling-rearing phase was determined by the estimated age of the oldest chick. Estimates were made during banding visits to the nest in mid nestling-rearing period and were based on feather development and comparisons to Nelson's (1970) drawings of chicks.

We divided the day into six 4-hour time-blocks covering the 24-hour period. The first 4-hour time-block began at midnight Alaska Daylight Time (ADT), two hours before solar midnight in Interior Alaska. Lack of daylight precluded some observations in the first time-block. Where possible, we sampled activity for a minimum of one hour within each time-block at each nest during each phase. In all years, however, observations were concentrated between 8:00 and 17:00 ADT. We sampled behavior during 37, 65, 183, 175, 141, and 59 observation blocks from time-blocks 1 through 6 respectively.

For analyses, we grouped one-minute scan samples by specific 4-hour time-blocks, referred to as "observation blocks". We grouped scans to avoid autocorrelation in the data from one-minute scans. Scans were eliminated from the total number in an observation block if visibility was poor or gender of the parent falcons was indistinguishable. Observation blocks were discarded if the total number of scans within a given observation block was less than 60, if visibility was poor, or if the sexes remained indistinguishable throughout the observation block. Thus, the data used in analyses were collected during a total of 660 observation blocks over the three years.

Observations of adults at the same nest, but in different years, were considered independent.

Two video cameras equipped with 250 mm lenses and 2X extenders were employed to record behaviors of adults continuously at or near the nest scrape during observations. During incubation and nestling-rearing periods, one camera was focused on the nest ledge, while the other was focused on the attending adult. During the post-fledging period, we focused on visible fledglings or adults as their visibility allowed. Videotapes confirmed ledge attendance during periods when incubating or brooding adults were not directly visible to observers.

We measured weather parameters every hour from the observation site, including temperature ($^{\circ}\text{C}$), wind speed (km/h), and precipitation. Precipitation was assessed as none, low (drizzle or light rain), medium (steady rain), or high (down pour). We averaged temperature and wind speed over each observation block, and for precipitation we used the highest level that occurred in each observation block.

Sample Units and Statistical Analyses

To calculate ledge attendance by each member of a pair, we divided the number of minutes the female or male spent at the nest ledge or scrape by the number of minutes in the observation block. We used female plus male ledge attendance as a measure of total ledge attendance by a pair. As with ledge attendance, we measured area attendance of each parent by dividing the number of minutes each parent spent at the nest ledge or in the nest area (within 200 m of the ledge or scrape) by the number of minutes in the observation block. Likewise, we used female plus male area attendance to estimate total area attendance by the pair. Similarly, the sample unit for time-activity budgets was the number of minutes the parent spent performing a particular activity divided by the total number of minutes per observation block.

We used analysis of variance (ANOVA) and Bonferroni's multiple comparison procedure to detect differences in attendance patterns among stages of the nesting cycle, time-blocks, and nesting pairs. We also examined the significance of three weather variables (temperature, wind speed, and precipitation) on attendance using linear regression. For analysis of patterns in ledge attendance, we did not include data from the post-fledging stage of the nesting cycle because ledge attendance was rare. To investigate gender roles in nesting activities we examined the ratio of female attendance to total attendance for departures from 50%, which would indicate unequal attendance by the two sexes. We also assessed changes in the ratio across stages.

We used ANOVAs and Bonferroni's multiple comparison procedure to assess differences in time-activity budgets with stage of the nesting cycle, and paired t-tests (or paired signed rank tests for non-normal data) to compare time-activity budgets between the sexes. For activities that were performed infrequently, we used χ^2 tests for homogeneity to test for differences between sexes. All tests were conducted at the 0.05 α level. Means are reported as $\bar{x} (\pm \text{SE})$.

We used logit transformations ($\log(Y/(1-Y))$) to normalize data where necessary. When logit transformations were necessary for total nest attendance, we converted total attendance to a true ratio by dividing the number of minutes the female spent at the nest ledge or scrape plus the number of minutes the male spent at the nest ledge or scrape, by twice the number of minutes per observation block for total ledge attendance. Similarly, we divided the number of minutes the

female spent either at the nest ledge or in the nest area (within 200 m of the ledge or scrape), plus the number of minutes the male spent either at the nest ledge or in the nest, by twice the number of minutes per observation block to calculate total area attendance. Because response variables included many values equal to 0 or 1, we added 0.5 times the minimum value of the response variable to Y for each proportion to avoid zero in the denominator or numerator of the logit transformed term. Although some analyses were performed with transformed data, we report arithmetic means and standard errors calculated from untransformed data.

RESULTS

Nest Attendance

Ledge attendance differed among stages of the nesting cycle. Through the course of the nesting cycle, ledge attendance declined, after controlling for nesting pair ($F_{3, 504} = 774$, $P < 0.0001$; Figure 7.1a). During incubation, total ledge attendance averaged 0.99 (± 0.018) among 24 nests. During the early nestling-rearing stage, total ledge attendance was initially high but gradually decreased to chick age 11 days ($r^2 = 0.38$, $P = 0.025$; Figure 7.2). Most visits to the nest ledge during subsequent stages were limited to prey deliveries and feeding of young; thus ledge attendance was low following the early nestling-rearing stage (Figure 7.1a). Similarly, area attendance declined with nesting stage, after controlling for nesting pair, but not as markedly ($F_{4, 661} = 63$, $P < 0.0001$; Figure 7.1b), with lowest levels during post-fledging ($P < 0.05$).

The ratio of female attendance to total attendance is an indication of the division of labor within a pair. Both the ratio of female ledge attendance to total ledge attendance and the ratio of female area attendance to total area attendance differed from 50% (t-stat = 11.9, $P < 0.0001$, $n = 660$ and t-stat = 9.3, $P < 0.0001$, respectively).

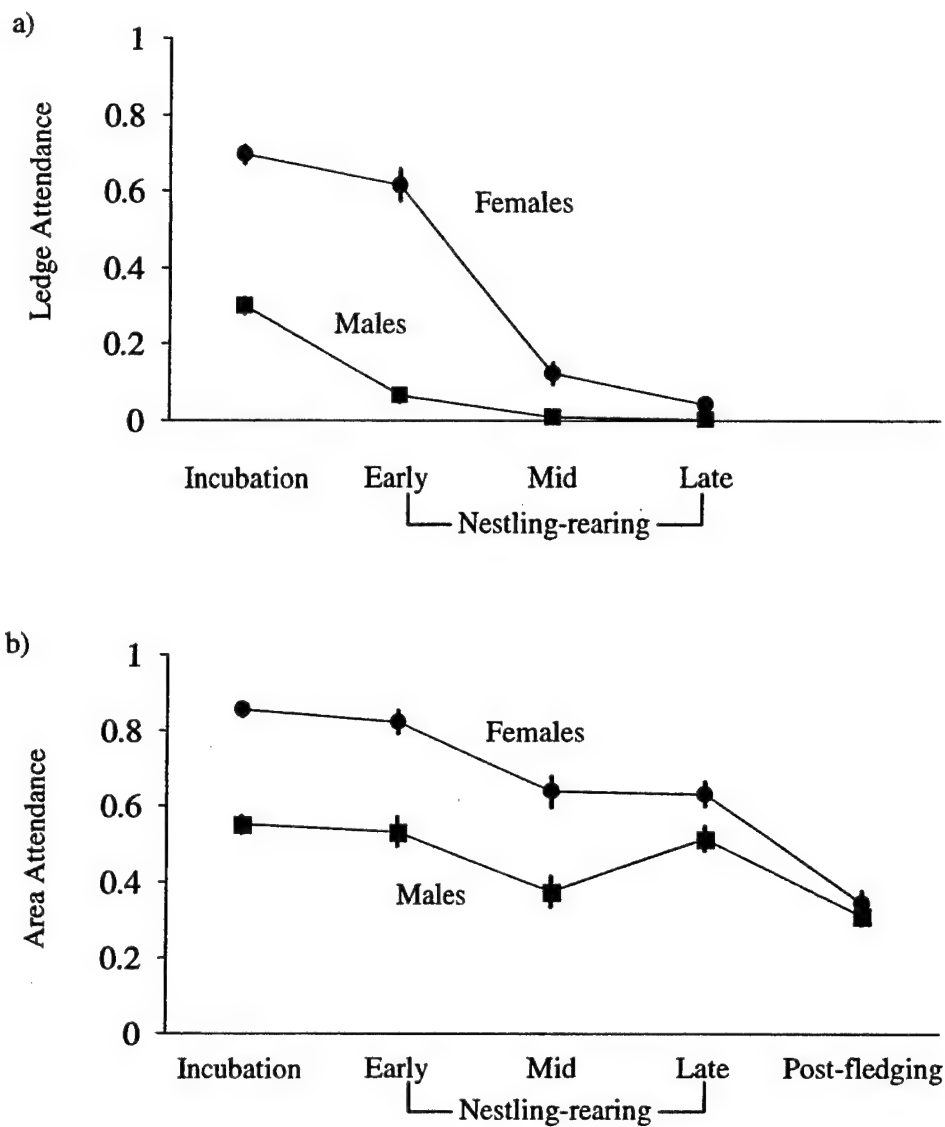
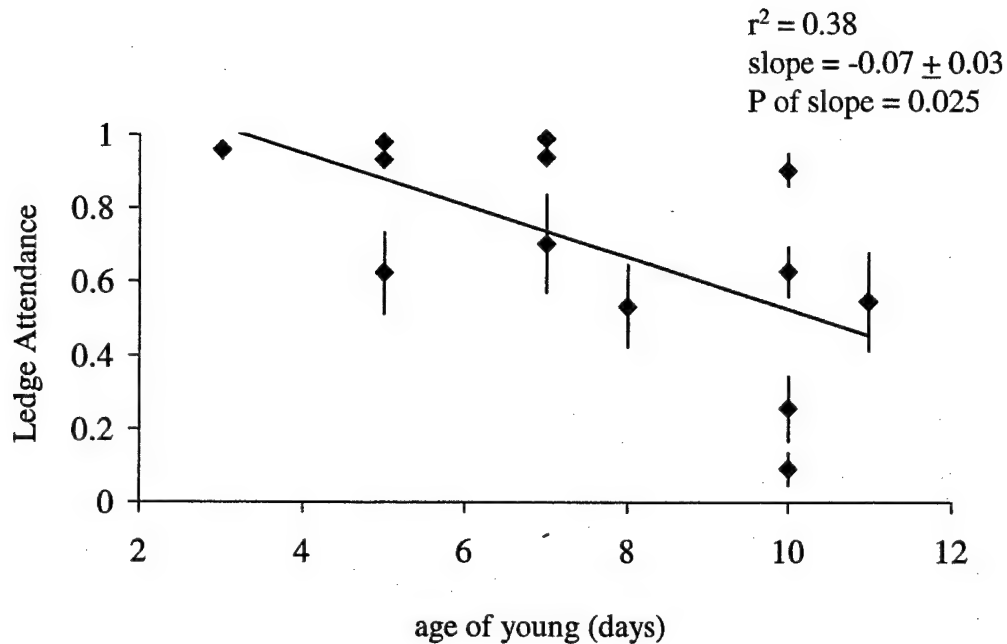
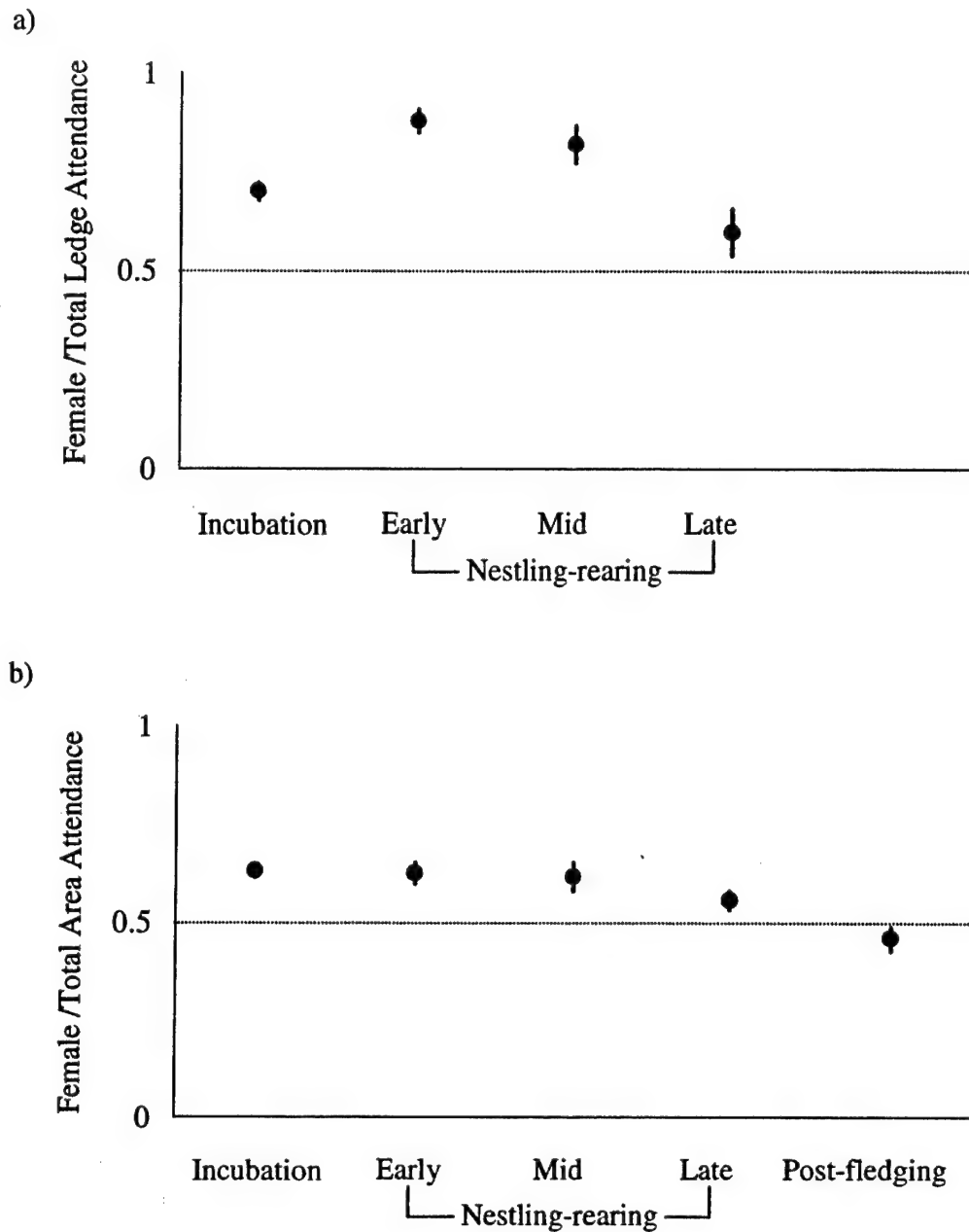


Figure 7.1a & b Nest attendance (\pm SE) as a function of state of the nesting cycle by Peregrine Falcons breeding along the Tanana River, Alaska



Figures 7.2 *Total ledge attendance (\pm SE) per nest during early nestling-rearing in relation to chick age by Peregrine Falcons breeding along the Tanana River, Alaska*

Furthermore, these ratios for both ledge and area attendance differed among nesting stages, after accounting for nesting pair ($F_{3,411} = 6.18$, $P = 0.0004$; and $F_{4,632} = 11.22$, $P < 0.0001$, respectively; Figure 7.3). The ratio of female ledge attendance to total ledge attendance was greater than 0.50 during all stages of the nesting cycle (Figure 7.3a). The ratio increased from incubation to early nestling-rearing ($P < 0.05$) and then decreased in subsequent stages of the nesting cycle (Figure 7.3). Unlike the ratio of female ledge attendance to total ledge attendance, the ratio of female area attendance to total area attendance decreased with each consecutive stage of the nesting cycle, after accounting for nesting pair (Figure 7.3b). During post-fledging the ratio of female area attendance to total area attendance was actually less than 0.50 (95% confidence interval: 0.38 to 0.49).



Figures 7.3a & b The ratio of female attendance to total attendance (\pm SE) as a function of nesting stage of Peregrine Falcons breeding along the Tanana River, Alaska

There was no difference in total ledge attendance among different time-blocks, after accounting for stage of the nesting cycle and nesting pair ($P > 0.05$ for family-wise comparisons); however, area attendance did differ among time-blocks ($F_{5, 659} = 4.81$, $P = 0.0003$). Specifically, area attendance was lower ($P < 0.05$) during time-block 1 (0:00 hrs to 04:00 hrs; $0.87 (\pm 0.11)$) and time-block 6 (20:00 hrs to 24:00 hrs; $1.01 (\pm 0.4)$) than time-block 3 (08:00 hrs to 12:00 hrs; $1.26 (\pm 0.06)$). Although both sexes exhibited this attendance pattern in the nest area, it was only

significant among males. Males had higher attendance during time-block 3 than other time-blocks ($F_{5, 659} = 5.02$, $P = 0.0002$).

None of the three weather variables (temperature, wind speed, or precipitation) explained a significant proportion of the variation in attendance while controlling for nesting stage and nesting pair.

Differences in nest attendance among pairs were most obvious during incubation. During this stage, differences in area attendance among pairs were highly significant ($F_{23, 209} = 4.45$, $P < 0.0001$). When separated by sex, differences in area attendance among both males and females were highly significant ($F_{23, 209} = 2.48$, $P = 0.0004$, $F_{23, 209} = 2.36$, $P = 0.0009$, respectively; Figure 7.4). However, there was no correlation between female area attendance and that of her mate (two-sided t -test for a test that the slope is zero = -0.53, $P = 0.60$). Among successful pairs, females that attended the nest area more during raised more young, but this trend only approached significance (two-sided t -test for a test that the slope is zero = 2.0, $P = 0.061$; Figure 7.5). Male area attendance was negatively correlated with female ledge attendance (two-sided t -test for a test that the slope is zero = -4.61, $P = 0.0001$). Finally, while total ledge attendance did not differ among pairs (Kruskal-Wallis Test statistic = 29.09, $P = 0.18$), the division of labor between the sexes did vary among pairs ($F_{23, 209} = 1.83$, $P = 0.0155$, and $F_{23, 209} = 1.77$, $P = 0.0208$, for differences among females and males respectively; Figure 7.6).

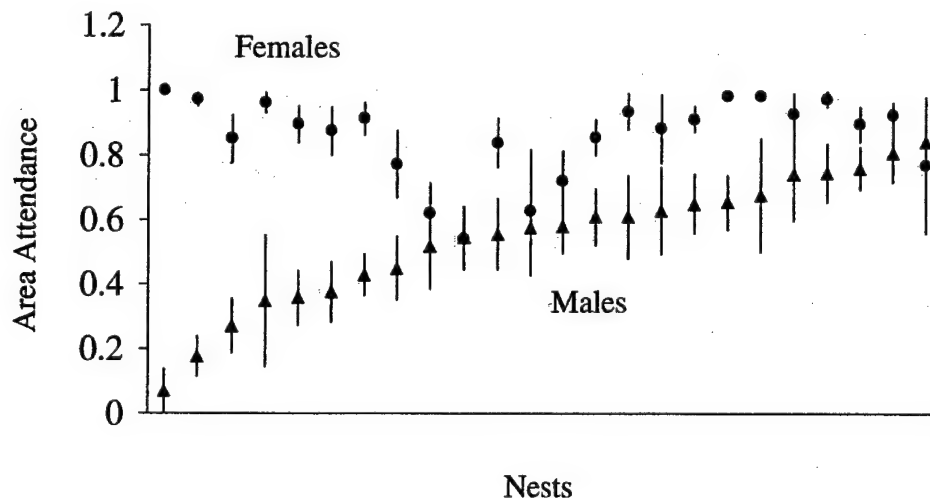


Figure 7.4 Differences in area attendance (\pm SE) during incubation among Peregrine Falcon pairs breeding along the Tanana River, Alaska, in ascending order of male area attendance

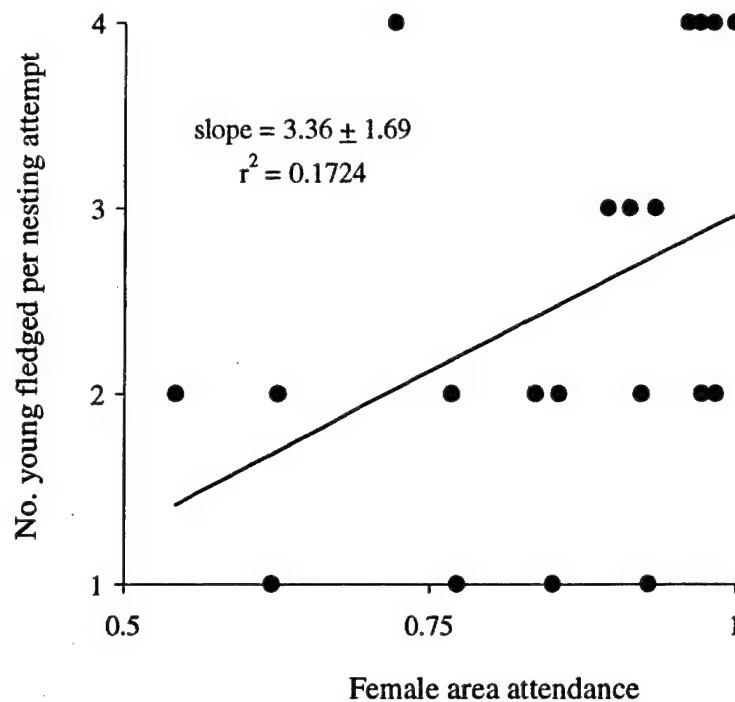


Figure 7.5 *Number of young fledged per nesting attempt among successful nests in relation to female area attendance during incubation in Peregrine Falcons breeding along the Tanana River, Alaska*

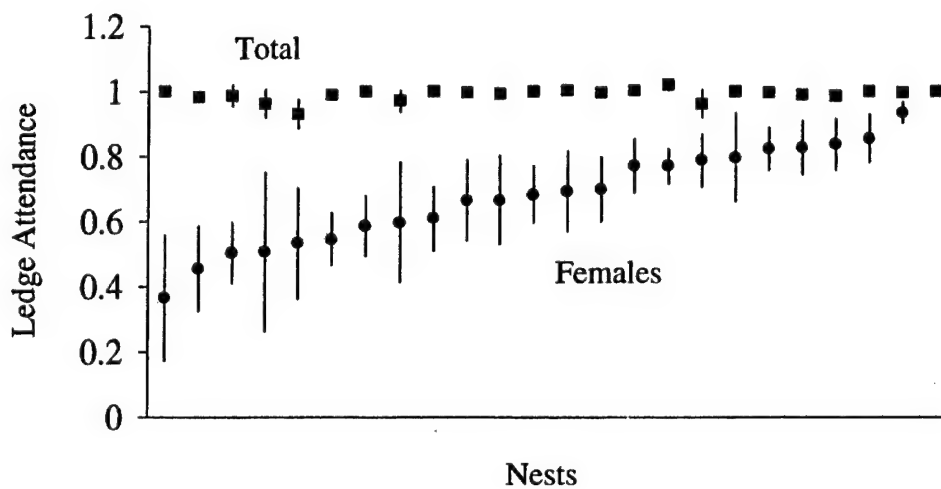


Figure 7.6 *Differences in ledge attendance (\pm SE) during incubation among Peregrine Falcon pairs breeding along the Tanana River, Alaska, in ascending order of female ledge attendance.*

Time-activity Budgets

For both females and males, mean proportion of time spent in each activity per observation block changed significantly with nesting stage, except for the activity category "females feeding self", after accounting for nesting pair (Tables 7.2 and 7.3). On average, females spent over twice as much time incubating ($68.4 \pm 2.2\%$) as males ($29.0 \pm 2.1\%$; $P < 0.0001$, paired *t*-test). Females brooded young much more than did males during early nestling-rearing ($P < 0.0001$, paired *t*-test; Figure 7.7a), though levels of this activity were lower than during incubation for both sexes ($P < 0.05$ for both).

Perching time at the nest area also differed among nesting stages and between sexes. Mean proportion of time spent perching by females during incubation, early nestling-rearing, and post-fledging was lower than during mid and late nestling-rearing ($P < 0.05$; Figure 7.7b). Perching time in males was lower during incubation and post-fledging than during early and late nestling-rearing, whereas perching time during mid nestling-rearing was not significantly different from either group ($P < 0.05$). Comparing the incidence of perching between the sexes, females perched less than males during incubation and early nestling-rearing ($P = 0.022$ and $P = 0.0078$, respectively; paired signed rank tests), but more than males during mid and late nestling-rearing ($P = 0.029$ and $P = 0.0006$, respectively; paired signed rank tests; Figure 7.7b). During post-fledging, the incidence of perching did not differ between the sexes ($P = 0.78$; paired signed rank tests; Figure 7.7b).

Table 7.2 *Time-activity budgets in relation to stage of the nesting cycle for female Peregrine Falcons breeding along the Tanana River, Alaska. Significant differences are reported.*

Stage of the nesting cycle	n ^a	Activity category				
		Incubate /brood	Perch Perch	Feed self	Feed young	Fly
Incubation	210	68.4 (2.2) ^b	18.4 (1.7)	0.33 (0.08)	-	0.7 (0.1)
Early Nestling-rearing	91	42.9 (4.1)	35.6 (3.5)	0.07 (0.07)	3.7 (0.5)	2.0 (0.6)
Mid Nestling-rearing	80	4.8 (1.9)	53.6 (4.0)	0.01 (0.06)	1.9 (0.4)	2.1 (0.4)
Late Nestling-rearing	122	-	59.6 (3.1)	0.33 (0.01)	1.0 (0.2)	2.7 (0.5)
Post-fledging	157	-	34.7 (2.9)	0.55 (0.02)	0.2 (0.8)	2.4 (0.7)
<i>F</i> ^c	-	86.1	28.2	0.42	25.0	7.9
<i>dfn, dfd</i> ^d	-	2, 349	4, 659	4, 659	3, 449	4, 659
<i>P</i>	-	<0.0001	<0.0001	0.80	<0.0001	<0.0001

^a n = number of observation blocks per stage for all nests combined.

^b mean percent time (SE)

^c *F*-tests took into account differences among pairs.

^d dfn = degrees of freedom numerator, dfd = degrees of freedom denominator

- = not applicable

Table 7.3 Time-activity budgets in relation to stage of the nesting cycle for male Peregrine Falcons breeding along the Tanana River, Alaska. Significant differences are reported.

Stage of the nesting cycle	n ^a	Activity category				
		Incubate/brood	Perch	Feed self	Feed young	Fly
Incubation	210	29.0 (2.1) ^b	25.8 (1.2)	0.16 (0.08)	-	1.4 (0.2)
Early Nestling-rearing	91	2.4 (0.9)	47.8 (3.7)	0.35 (0.14)	0.74 (0.30)	2.4 (0.5)
Mid Nestling-rearing	80	-	36.6 (3.7)	0.28 (0.11)	0.13 (0.07)	2.0 (0.4)
Late Nestling-rearing	122	-	49.3 (3.0)	0.25 (0.10)	0.14 (0.07)	2.9 (0.5)
Post-fledging	157	-	31.9 (2.4)	0.15 (0.05)	0.01 (0.01)	2.7 (0.3)
F ^c	-	40.9	10.76	2.32	3.05	3.08
dfn, dfd ^d	-	1, 300	4, 659	4, 659	3, 449	4, 659
P	-	<0.0001	<0.0001	0.056	0.029	0.016

^a n = number of observation blocks per stage for all nests combined.

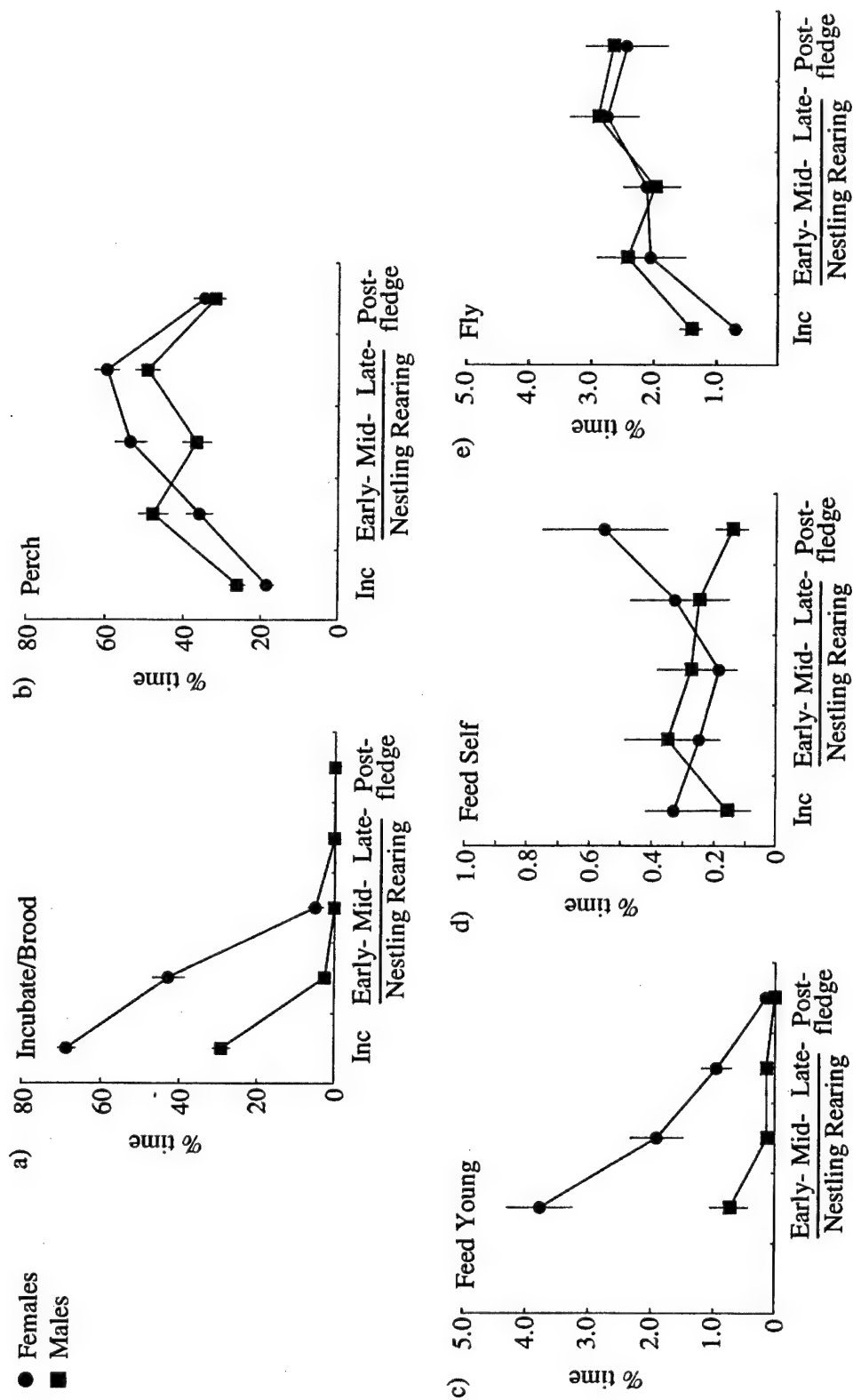
^b mean percent time (SE)

^c F-tests took into account differences among pairs.

^d dfn = degrees of freedom numerator, dfd = degrees of freedom denominator

- = not applicable

Figure 7.7a-e Time-activity budgets (\pm SE) in relation to stage of the nesting cycle for Peregrine Falcons breeding along the Tanana River, Alaska.



Other activities that occurred infrequently either differed with nesting stage, gender, or both. Mean proportion of time spent feeding young gradually decreased with stage of the nesting cycle for both females and males, most dramatically between early and mid nestling-rearing for females ($P < 0.05$, Figure 7.7c). Comparing sexes, females fed young during a greater proportion of observation blocks than males in each stage of the nestling-rearing period ($P < 0.0001$ (early), $P < 0.0001$ (mid), and $P = 0.0088$ (late); χ^2 tests for homogeneity). Males fed themselves in the nest area more during nestling-rearing than both incubation and post-fledging. Females fed themselves in the nest area during more observation blocks (79 of 660) than males (51 of 660), a difference of 35.4% ($\chi^2 = 6.2$, $df = 1$, $P = 0.013$, test for independence between sex and activity with Yates' correction; Figure 7.7d). Finally, the proportion of time spent flying by females ($1.6 \pm 0.19\%$) and males ($2.4 \pm 0.20\%$) was low overall. The incidence of flying was higher for females during nestling-rearing than during incubation ($P < 0.05$; Figure 7.7e) and higher among males during late nestling-rearing and post-fledging than during incubation ($P < 0.05$; Figure 7.7e).

DISCUSSION

Stage of the nesting cycle and gender were prominent factors influencing nest attendance and time-activity budgets (Figures 7.1-7.3 and 7.7a-e). Nest attendance and activities associated with low energetic cost dominated early stages of the nesting cycle (Figure 7.1a). This implies that nesting success during incubation and chick brooding could be disproportionately affected by factors like disturbance, because disturbance may shift activities away from thermoregulation of eggs and young chicks and towards territorial defense. Indeed, peregrine chicks are sensitive to extreme temperatures during breeding (Palmer, 1988). Following chick brooding, perching by females and flying by both sexes increased through the nestling-rearing stage (Figures 7.7b and 7.7e). For females, this likely allowed for increased hunting by both perch-hunting and flight-hunting when chicks were larger and had higher physiological demands. Similarly, males spent more time flying, an activity linked to hunting (Ratcliffe, 1993), perhaps to provision older chicks.

The increasing energetic requirements of large chicks combined with the declining physiological state of parents may dictate gender roles as well (Court et al., 1990). The increased proportion of female ledge attendance to total ledge attendance during early nestling-rearing from incubation may reflect the new pressure on males to provide for both young chicks and females, while the chicks still require brooding, performed primarily by the female. General accounts of peregrine breeding behavior indicate females assume the majority of incubating and brood rearing, and

males conduct most of the hunting (Palmer, 1988; Ratcliffe, 1993). Our results on nest attendance and time-activity budgets support these results. However, our results also show a steady decline in the ratio of female area attendance to total area attendance with the progression of the nesting cycle may indicate that larger chicks compel females to hunt for larger or more prey. Because of their larger size, female raptors can deliver larger prey (Palmer, 1988; Mearns, 1983), and larger prey are sometimes associated with longer periods away from the nest area (Palmer, 1999). Alternatively, females may spend less time guarding the nest area with progression of the nesting cycle because young are more independent and require less thermoregulation by parents.

During the post-fledging stage, parental nest area attendance was lower than during other stages. Low attendance during post-fledging may have reflected avoidance by parents of begging young (Sherrod, 1983). As young gained the coordination to feed themselves during nestling-rearing, the amount of time parents fed young decreased (Figure 7.7c). Also, post-fledging brings on a stage when chicks are less attached to the nest area, and thus free to hunt and eat away from the nest area with parents (Sherrod, 1983), as they prepare for migration. These attendance and activity patterns are typical of other raptors (Wakeley, 1978; Levenson, 1981; Collopy, 1984; Collopy and Edwards, 1989)

Another factor that may influence Peregrine Falcon nest attendance is the daily rhythm of activity in their prey. Peregrines feed primarily on other birds (Ratcliffe, 1993), and passerines, shorebirds, and waterfowl display circadian rhythms of activity, even in the arctic summer (Armstrong, 1954). Therefore, we expected falcons to trade-off high levels of nest attendance for hunting opportunities early and late in the day (Pyke et al., 1977). The data supported this hypothesis; area attendance during early morning and late evening was lower than during late morning. The data were also in agreement with Bird and Aubry (1982), who reported more hunting attempts and more prey captured by Peregrine Falcons during the first hours of daylight.

Weather was not a significant factor influencing nest attendance, after accounting for stage of the nesting cycle and nesting pair. Although we observed parent Peregrine Falcons during inclement weather in the three breeding seasons, the vast majority of observation blocks did not include extreme weather conditions. Indeed, average wind speed was below 7 mph for 90% of observation blocks, 80% of average temperatures were between 9^o C (48^o F) and 22.5^o C (72.5^o F), and 83% of observation blocks included no rainfall. In the absence of more observation blocks with adverse weather it may be difficult to detect a significant correlation between weather conditions and behavior. However, weather can influence Peregrine Falcon breeding success and

behavior. For example, periodic yet rare severe weather over the course of 13 years influenced chick survival of Peregrine Falcons in the Northwest Territories (Bradley et al., 1997).

Although female Peregrine Falcons typically perform most of the incubating (Cade, 1960; Nelson, 1970; Palmer, 1988; Ratcliffe, 1993; this study), we found gender roles were not consistent among pairs. Some females allocated nearly all of their time towards incubation, while other pairs divided the role of incubation more evenly between the sexes (Figure 7.6). Cade (1960) found similar variability in incubation sharing between the sexes among captive breed Peregrines. Differences among pairs in gender roles may be attributable to a variety of conditions, such as mate quality, territory quality, food availability, or mate age. Males that allocate more time to hunting, may enable females to focus on consistent nest guarding. We found that male area attendance was negatively correlated with female ledge attendance. "Quality" females that sat tight, evidently had mates that hunted for them. In turn this may have lead to production of more young, as seen in the apparent relationship between higher female area attendance and more chicks fledged (Figure 7.5).

Others report congruent findings among other raptors. Ward and Kennedy (1996) attributed higher nestling survival among supplementally fed Northern Goshawks (*Accipiter gentilis*) chicks to higher female nest attendance. Higher female nest attendance, presumably deterred predators. Similarly, Newton (1986) remarked that high female nest attendance among Sparrowhawks (*Accipiter nisus*) was associated with better chick growth and survival.

In summary, we found that several intrinsic and extrinsic factors influenced nest attendance and time-activity budgets of nesting Peregrine Falcons. We observed prominent differences among stages of the nesting cycle and between the sexes. While sexual differences in area attendance were pronounced during early stages of the nesting cycle, sexual differences became negligible after the young fledged. Nest area attendance was lowest during early mornings and late evenings, coinciding with periods when prey were most active. Finally we found that gender roles varied among pairs, and among successful pairs, females with higher attendance in the nest area during incubation appeared more likely to fledge more young. Eggs appeared to require strict ledge attendance, yet variation in area attendance may also be linked to reproductive parameters like number of chicks fledged. Further investigations should examine the influence of mate quality and territory quality on the division of labor in relation to reproductive success.

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CHAPTER 8

FACTORS INFLUENCING NESTLING PROVISIONING RATES OF PEREGRINE FALCONS IN EAST-CENTRAL ALASKA

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ABSTRACT

We examined factors influencing nestling provisioning rates among Peregrine Falcons (*Falco peregrinus*) breeding along the Tanana River, Alaska in 1995-1997. Perching birds (Passeriformes) composed the majority (54.3%) of prey delivered to the nest, whereas ducks and grebes composed the majority of prey biomass (60.8%). Both delivery rates of prey and estimated prey mass increased with brood size, after accounting for stage of the nesting cycle. Additionally, average prey size increased with increasing brood size. Prey size was positively correlated with the length of time an adult was absent from the area of the nest prior to prey delivery. If time away from the nest is correlated to distance traveled while foraging, then this supports the prediction that prey size should increase as distance traveled to obtain prey increases. Finally, we found that although delivery rates of prey per nestling decreased with increasing brood size, estimated mass delivered per nestling did not vary with brood size. Peregrine Falcons apparently maintained provisioning rates per nestling as brood size increased by increasing average prey size.

INTRODUCTION

Parent birds must provision nestlings adequately to ensure growth and survival of nidicolous young. Parents are limited in their ability to provide for nestlings by both environmental conditions and physiological constraints and parents confront a trade-off between investing in present versus future reproduction (Trivers 1972). Deerenberg et al. (1995) supported the existence of a trade-off between present and future reproduction by showing that daily energy expenditure of breeding European Kestrels (*Falco tinnunculus*) increased with artificially enhanced brood size, and was negatively correlated with subsequent survival of parents. In addition, although parents raising larger broods contribute more offspring to the population, the fitness of each fledgling from large broods may be lower than the fitness of fledglings from smaller broods. Dijkstra et al. (1990) demonstrated that European Kestrel nestlings from enlarged broods had lower growth rates in comparison to those from either natural or reduced broods. Provisioning broods with less food per nestling presumably reduces both pre- and post-fledging survival and thus current reproductive success (Drent and Daan 1980).

Lack (1954) and Gibb (1955) proposed that parent birds work as hard as they can to feed young, and that chicks from larger than average broods are fed less than nestlings in average-sized broods. According to

their hypothesis, provisioning rates per nestling should decline in a convex curve with increasing brood size. Royama (1966) argued that larger broods are fed less because they have less surface area per unit volume and greater thermal inertia, and thus need less food to maintain homeothermy. Nur (1984) found that feeding frequency per nestling declined with a concave curve in studies on Blue Tits (*Parus caeruleus*), suggesting that nestlings from larger than average broods were fed less than nestlings in average-sized broods. A survey of the literature on feeding frequencies of nestlings indicated that concave declines in per nestling feeding frequencies with increasing brood size are the norm (Nur 1987).

Feeding frequency is not well understood for raptors. We examined the relationships between prey delivery rate, prey size, mass delivery rate, and brood size. First, if Peregrine Falcon pairs are flexible in how they meet food requirements of nestlings, we expected to find differences among pairs in prey delivery rates and prey size in relation to brood size. We anticipated that mass delivery rates (g hr^{-1}), a function of prey delivery rates (items hr^{-1}) and prey size (g item^{-1}), increase with increasing brood size.

Second, Peregrine Falcons select a wide variety of predominantly avian prey species and sizes, and hunt over large local geographical areas (Ratcliffe 1993, Enderson and Craig 1997); thus, they are good subjects to examine prey size-distance relationships in foraging. Optimal foraging theory predicts that prey size should increase as distance traveled to obtain prey increases (Pyke et al. 1977, Schoener 1979). For instance, Martindale (1983) found that foraging distance was correlated positively with prey size among Gila Woodpeckers (*Melanerpes uropygialis*). Because it requires more time to commute to and from foraging areas further from the nest site, the time an adult is away from the nest prior to a prey delivery may be correlated with distance traveled. We expected a positive correlation between time away from the nest prior to a delivery and size of prey delivered.

Finally, raising larger broods can produce more fledglings, but can be more energetically costly for parents (Deerenberg et al. 1995). We expected parents to deliver more food to larger broods, but due to the energetic costs of provisioning, pairs with larger broods would not be expected to provide as much food per nestling as pairs with smaller broods. Alternatively, if parents fully compensate for each additional nestling in a brood, we would expect per nestling provisioning rates to be similar, regardless of brood size.

METHODS

Study Area

The study area encompassed a 250-km stretch of the Tanana River between Tok and Fairbanks, Alaska (from $63^{\circ}8' \text{ N}$, $143^{\circ}36' \text{ W}$ to $64^{\circ}18' \text{ N}$, $148^{\circ}45' \text{ W}$). In 1995, the study area extended from Tanacross to Sawmill, an approximately 110-km stretch of river (hereafter the "upper stretch"). In 1996 and 1997, we

included an additional 65-km section of the river from Delta to Salcha (hereafter the "lower stretch"). Observations were initiated each year after ice break-up in mid-May, and continued until the young had fledged and left the area of the nest in late August/early September. A crew of two to four observers recorded data at each Peregrine Falcon nest and two separate crews were in the field throughout the season.

We selected nests for observation based on access to observation sites opposite cliffs and visibility of the nest ledge from the observation sites. Nests were situated on bluffs overlooking the river. We established observation sites across at least one channel of the river and about 300 m from nests to observe prey deliveries.

Sample Sizes

We observed 10 nests in 1995, 9 nests in 1996, and 10 nests in 1997 from a total of 17 nest sites, where a nest site is an area that contains, or historically contained, one or more nests (or scrapes) within the home range of a pair of mated birds (Steenhof 1987). Of these sites, we observed eight sites in one year only, six sites in two years, and three sites during all three years of the study. We made observations during the nestling-rearing and post-fledging phases. Of the 10 nests observed in 1995, we observed all 10 during nestling-rearing and 4 during post-fledging. In 1996, we recorded provisioning rates at 8 nests during nestling-rearing. One nest failed prior to fledging; we observed the 7 remaining nests plus an additional nest during the post-fledging stage. In 1997, we observed all 10 nests during both nestling-rearing and post-fledging. For analysis, we subdivided observations into four stages of the nesting cycle: early nestling-rearing (0-10 days post-hatch), mid nestling-rearing (11-24 days), late nestling-rearing (25 days to fledging), and post-fledging (~40+ days). Stage was determined during visits to the nest to band young. During early, mid, and late nestling-rearing, and post fledging, we made observations at 12, 14, 18, and 22 nest sites respectively, during all years combined.

We sampled provisioning rates during most of the daylight period at each nest observed during nestling-rearing and again at each nest observed during post-fledging, with the exception of one nest during nestling-rearing that was observed during only one 4-hr period. In both years, however, observations were concentrated from 0800 H to 1700 H Alaska Daylight Time (ADT).

Two video cameras equipped with 250 mm lenses and 2X extenders were employed to record prey deliveries continuously during observation sessions from observation sites. In 1995, we used Canon L2 Hi-8 mm and Sony CCD-FX430 8 mm video cameras, and in 1996 and 1997 we used Canon L2 cameras. During the nestling-rearing stage, one camera was focused on the nest ledge, while the other was focused

on the attending adult. During the post-fledging stage, we focused on fledglings or adults as their visibility allowed.

Provisioning Rates

We used binoculars, 15-60 X spotting scopes, and Questar ® telescopes to aide our observations. During the nestling-rearing period at least two (1995) and three (1996, 1997) observers recorded data. At least four observers recorded data during the post-fledging stage of the nesting cycle in all years.

At each nest site, we recorded the number of prey deliveries, the estimated size class of each prey item, and the type of prey delivered (identified to species whenever possible). As a measure of provisioning rates, we estimated the mass of those prey identified to species using average body mass of that species (Dunning 1993). For prey identified only to genus or family, we used the mean mass of all the species of that genus or family (Dunning 1993) that regularly occur in the study area, except in the case of shorebirds, which span a wide range of masses. We classified shorebirds and prey not identified to species, genus, or family into the following size classes: small (9-50 g), medium (51-200 g), large (201+ g), or unknown, to assign them an estimated mass. For shorebirds and prey identified only to size-class, we used the median mass of all species of that size class known to regularly occur in the study area (30 g, 125 g, and 641 g for small, medium, and large items, respectively). Prey of unknown size-class were categorized as medium-sized prey. We estimated mammalian prey masses from Burt and Grossenheider (1980). For analysis of prey size in relation to brood size, we included only those prey identified to the level of family and classified them as small (9-50 g), medium (51-200 g), or large (201+ g), based on the above method of mass assignments

We estimated mass delivery rates during each stage of the nesting cycle for each nest by averaging total mass delivered during 4-hr observation sessions. Similarly, we calculated prey delivery rates during each stage for each nest by averaging total number of prey delivered during 4-hr observation sessions. Finally, to estimate average mass per nest per stage, we divided the total estimated mass of prey delivered by the total number of items delivered per 4-hr observation session, and then calculated the mean for the total number of observation sessions. During a given stage of the nesting cycle we conducted an average of 5 (SD = 2.6) 4-hr observation sessions at a given nest, for a total of 182 observation sessions at all nests. Observation sessions were excluded from analyses if poor visibility persisted throughout the session. Regression analyses of one year of data from each nest were similar among years, so nests were treated independently between years.

We also examined the relationship between the length of time an adult was absent from the area of the nest prior to a delivery (time away) and the estimated mass of the prey delivered. For this analysis we

excluded the first item of every observation session and included only prey identified to species, genus, or family.

Average brood size of successful study nests at fledging was 2.55 (SD = 1.0, range = 1 - 4 nestlings, Chapter 6, this study), similar to average brood size throughout Interior Alaska (Cade 1960, Ambrose et al. 1988, Bente and Wright 1995). This included five nests with one chick, nine nests with two chicks, nine nests with three chicks, and six nests with four chicks. We observed four nests that experienced reductions in brood size prior to fledging: two from 3 to 1 chick, one from 3 to 2 chicks, and the last from 4 to 3 chicks.

Statistical Analyses

We used linear regression to assess the relationships of estimated number and mass of prey delivered and average estimated mass as a function of brood size, and of estimated mass as a function of time away. We used Analysis of Variance (ANOVA) and Bonferroni's multiple comparison procedure to assess differences in provisioning rates among stages of the nesting cycle. We used lack of fit F-tests to test the adequacy of straight-line regression models versus separate means models for comparisons between provisioning rates and brood size. Additionally, we used a χ^2 test to examine the relationship between prey size-class and brood size. Means are reported as $0 \pm \text{SE}$. We weighted means used for regression analyses based on the sample size of 4-hr observation blocks per stage. We log transformed mass delivery rates to meet the assumptions of the statistical test, but we report data on the non-transformed scale.

RESULTS

Taxonomic Composition of Prey

Of the 343 prey observed being delivered to nestlings, 201 (58.6%) were identified to some taxonomic group. Most of these prey (54.3%) were perching birds (Passeriformes), with shorebirds (23.5%), ducks and grebes (13.0%), and gulls and terns (6.5%) comprising most of the remainder (Table 8.1). Ducks and grebes were the most important prey category on a biomass basis, comprising 60.8% of total estimated prey biomass. Shorebirds followed at 14.1%, gulls and terns at 9.7%, and perching birds only 11.2% of total prey biomass. Small mammals were delivered on three occasions and comprised an estimated 1.1% of prey biomass.

Table 8.1. Frequencies of prey items observed and identified upon delivery to Peregrine Falcon nestlings at nests along the Tanana River, Alaska in 1995, 1996, and 1997.

Common Name (<i>Scientific Name</i>)	Age/Sex	Frequency	% Occurrence	Body Mass (g) ^a	% Total Prey Mass
Grebe spp. (Red-necked or Horned) (<i>Podiceps</i> spp.)		3	1.5	738	8.3
Mallard (<i>Anas platyrhynchos</i>)	female	2	1.0	1082	8.1
American Wigeon (<i>Anas americana</i>)	female	1	0.5	719	2.7
American Wigeon (<i>Anas americana</i>)	male	2	1.0	792	6.0
American Green-winged Teal (<i>Anas crecca</i>)	male	1	0.5	364	1.4
American Green-winged Teal (<i>Anas crecca</i>)	-	2	1.0	340	2.6
Scaup spp. (Greater or Lesser) (<i>Aythya</i> spp.)	male	1	0.5	891	3.3
Duck spp. (Anatinae spp.)	female	1	0.5	722	2.7
Duck spp. (Anatinae spp.)	-	6	3.0	746	16.8
Duckling (Anatinae spp.)	Juvenal	4	2.0	30	0.5
Duck/Grebe spp. (Anatinae spp. or <i>Podiceps</i> spp.)	-	3	1.5	745	8.4
<i>Total Ducks and Grebes (Anatinae and Podicipedidae)</i>		26	13.0		60.8
Red-necked Phalarope (<i>Phalaropus lobatus</i>)	-	1	0.5	34	0.1
Least Sandpiper (<i>Calidris minutilla</i>)	-	2	1.0	23	0.2
Lesser Yellowlegs (<i>Tringa flavipes</i>)	-	7	3.5	81	2.1
Yellowlegs spp. (Greater or Lesser) (<i>T. flavipes</i> or <i>T. melanoleuca</i>)	-	5	2.5	126	2.4
Solitary Sandpiper (<i>Tringa solitaria</i>)	Juvenal	1	0.5	48	0.2

Common Name (<i>Scientific Name</i>)	Age/Sex	Frequency	% Occurrence	Body Mass (g) ^a	% Total Prey Mass
Upland Sandpiper (<i>Bartramia longicauda</i>)	-	1	0.5	150	0.6
Spotted Sandpiper (<i>Actitis macularia</i>)	-	10	5.0	32	1.2
Spotted Sandpiper (<i>Actitis macularia</i>)	Juvenal	3	1.5	32	0.4
Shorebird spp. (<i>Scolopacidae</i> spp.) small	-	3	1.5	30	0.3
Shorebird spp. (<i>Scolopacidae</i> spp.) medium	-	14	7.0	125	6.6
<i>Total Shorebirds (Scolopacidae)</i>		47	23.5		14.1
Mew Gull (<i>Larus canus</i>)	-	1	0.5	404	1.5
Bonaparte's Gull (<i>Larus philadelphia</i>)	-	1	0.5	212	0.8
Gull spp. (Mew or Bonaparte's) (<i>Larus</i> spp.)	-	3	1.5	308	3.5
Gull nestling (<i>Larus</i> spp.)	-	2	1.0	125	0.9
Arctic Tern (<i>Sterna paradisaea</i>)	-	5	2.5	110	2.1
Gull/Tern spp. (<i>Larus</i> spp or <i>Sterna</i> spp.)	-	1	0.5	242	0.9
<i>Total Gulls and Terns (Laridae or Sternidae)</i>		13	6.5		9.7
Rock Dove (<i>Columba livia</i>)	-	1	0.5	355	1.3
Northern Flicker (<i>Colaptes auratus</i>)	-	1	0.5	142	0.5
Grouse spp. (<i>Bonasa umbellus</i> or <i>Dendragapus canadensis</i>)	-	1	0.5	337	1.3
Olive-sided Flycatcher (<i>Contopus borealis</i>)	-	1	0.5	32	0.1
Bohemian Waxwing (<i>Bombycilla garrulus</i>)	-	1	0.5	56	0.2
Black-billed Magpie (<i>Pica pica</i>)	-	2	1.0	178	1.3
Gray Jay (<i>Perisoreus canadensis</i>)	-	4	2.0	73	1.1

Common Name (<i>Scientific Name</i>)	Age/Sex	Frequency	% Occurrence	Body Mass (g) ^a	% Total Prey Mass
Gray Jay (<i>Perisoreus canadensis</i>)	Juvenal	1	0.5	73	0.3
Dark-eyed Junco (<i>Junco hyemalis</i>)	-	8	4.0	20	0.6
Cliff Swallow (<i>Hirundo pyrrhonota</i>)	-	1	0.5	22	0.1
Violet-green Swallow (<i>Tachycineta thalassina</i>)		6	3.0	14	0.3
Violet-green Swallow (<i>Tachycineta thalassina</i>)	Juvenal	1	0.5	14	0.1
Bank Swallow (<i>Riparia riparia</i>)	-	1	0.5	15	0.1
Tree Swallow/Violet-green Swallow (<i>T. bicolor</i> or <i>T. thalassina</i>)	-	2	1.0	17	0.1
Swallow spp. (Cliff, Tree, Violet-green, or Bank) (<i>Hirundinidae</i> spp.)	-	45	22.4	18	3.0
Swallow spp. (<i>Hirundinidae</i> spp.)	Juvenal	6	3.0	18	0.4
Yellow Warbler (<i>Dendroica petechia</i>)	-	1	0.5	10	0.1
Black-capped Chickadee (<i>Parus atricapillus</i>)	-	2	1.0	11	0.1
Townsend=s Solitaire (<i>Myadestes townsendi</i>)	-	1	0.5	34	0.1
Swainson's Thrush (<i>Catharus ustulatus</i>)	-	1	0.5	31	0.1
Varied Thrush (<i>Ixoreus naevius</i>)	-	1	0.5	77	0.3
American Robin (<i>Turdus migratorius</i>)	-	1	0.5	77	0.3
Thrush spp. (Gray-checked, Swainson's, or Hermit) (<i>Catharus</i> spp.)	-	1	0.5	32	0.1
small Passerine spp. (<i>Passeriformes</i> spp.)	-	22	10.9	30	2.5
<i>Total Perching Birds (Passeriformes)</i>		109	54.3		11.2

Common Name (<i>Scientific Name</i>)	Age/Sex	Frequency	% Occurrence	Body Mass (g) ^a	% Total Prey Mass
<i>Unknown Avian spp.</i>	-	142	-	-	-
Red Squirrel (<i>Tamiasciurus hudsonicus</i>)	-	1	0.5	240	0.9
Small Rodent (Rodentia)	-	2	1.0	30	0.2
<i>Total Small Mammal</i>		3	1.5		1.1
Total	-	(343)	201=100%	26,616 g = 100%	

a - We estimated prey mass using the average body mass of that species (Dunning 1993). For prey identified to genus or family, we used the mean mass of all the species of that genus or family (Dunning 1993) that regularly occur in the study area, except in the case of shorebirds which span a wide range of masses. We classified shorebirds into small (9-50 g) or medium (51-200 g) size classes based on estimated size in the field and assigned them the median mass of all species of that size class known to regularly occur in the study area (30 g and 125 g, respectively). We estimated mammalian prey masses from Burt and Grossenheider (1980).

Prey Size

Of the 343 prey that we observed being delivered to young, 232 items (67.6%) were identified to size category. Overall, more small items (126 or 54.3%) were delivered than either medium (69 or 29.7%) or large (37 or 15.9%) items (χ^2_2 goodness of fit test = 52, $P < 0.001$). When prey of all size categories were combined, there was a trend towards between brood size and size of prey (χ^2_6 contingency test for independence = 11.14, $P = 0.08$). We observed a trend towards fewer medium-sized items brought to broods of 2 ($P = 0.11$, analysis of standardized residuals). Additionally, parents of single-chick broods delivered no prey over 200 g, during 140 hours of observations, except for one delivery of a gull. (308 g). This analysis does not account for differences in the number of 4-hr observation sessions among brood sizes, however, we found a positive relationship between average prey size and brood size ($P < 0.05$, $r^2 = 0.15$, $n=66$), after accounting for stage of the nesting cycle, and weighting the regression by number of 4-hour observation sessions. Median prey size increased an average of 24% ($\pm 10\%$) with each additional nestling (Figure 8.1). Together these analyses indicate that Peregrine Falcons maintained provisioning rates for larger broods by increasing average prey size.

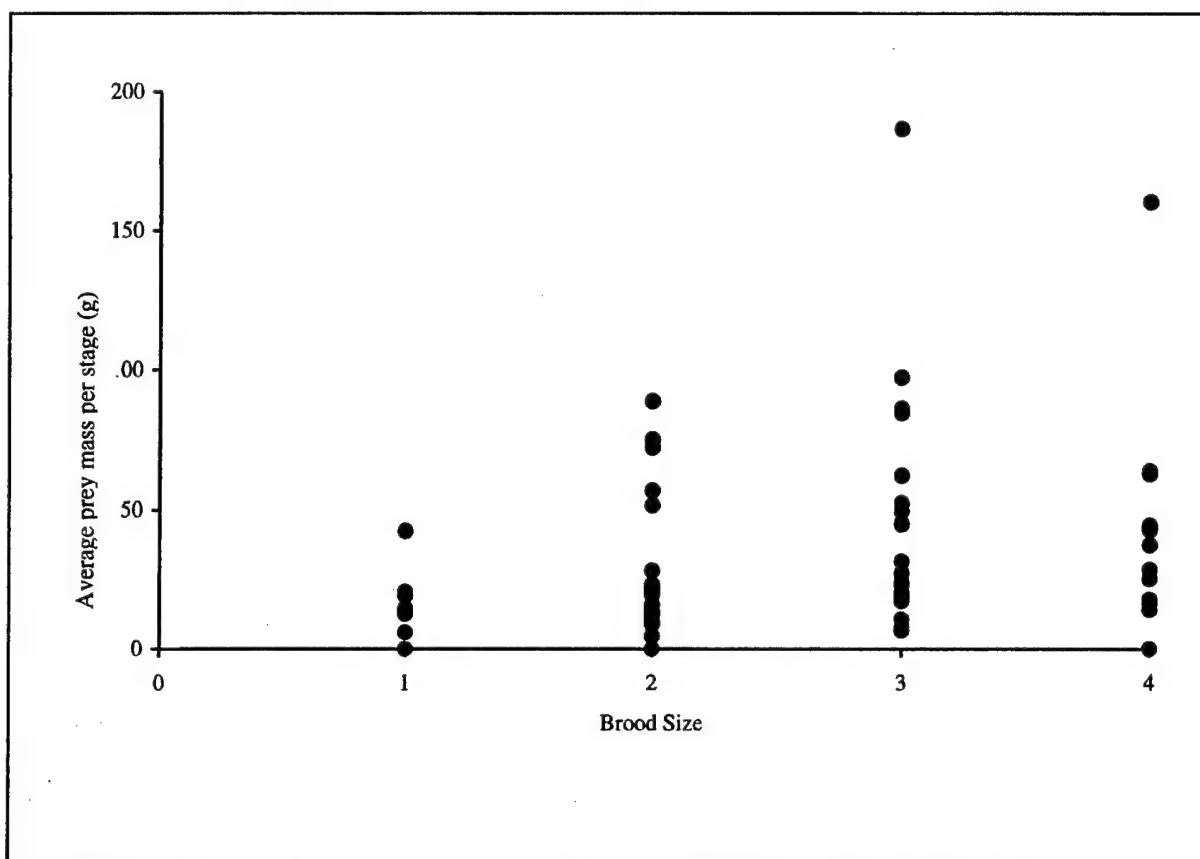


Figure 8.1. Average estimated mass of prey delivered per stage of the nesting cycle to Peregrine Falcon broods of various sizes along the Tanana River, Alaska

Time Away

There was a positive correlation between the time an adult was away from the nest area prior to a prey delivery (hrs) and estimated mass of delivered prey (slope = $0.51 [\log(\text{g}) \text{ hr}^{-1}] \pm 0.08$, $P < 0.001$, $r^2 = 0.29$, $n = 111$; Figure 8.2). This is driven by the inverse relationship between prey delivered and average mass (slope = -2.09 ± 0.27 , $P < 0.001$, $r^2 = 65.8$, $n = 66$) measured per stage per nest.

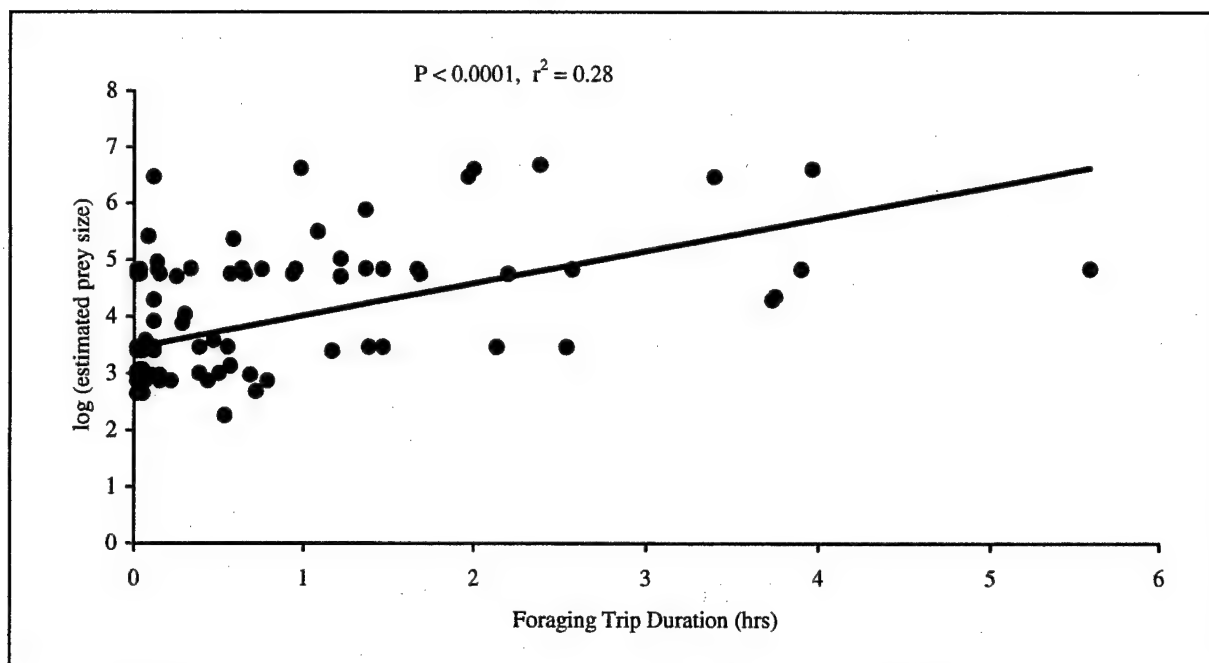


Figure 8.2. Time away from nest cliff prior to prey delivery as a function of estimated log(preY size) for Peregrine Falcons nesting along the Tanana River, Alaska

Stage of the Nesting Cycle and Prey Provisioning Rates

Prey delivered, average prey size, and mass delivery rates did not differ among stages of the nesting cycle ($F_{3,65} = 7.36$, $P < 0.05$, however, $P > 0.10$ for family-wise multiple comparisons; $F_{3,65} = 1.04$, $P > 0.3$; and $F_{3,65} = 1.19$, $P > 0.3$; respectively), although there was a trend toward lower mass delivery rates during post-fledging.

Brood Size and Prey Provisioning Rates

There was a positive relationship between brood size and both prey delivery rate ($r^2 = 0.35$, $P = 0.002$, $n=66$, Figure 8.3a) and mass delivery rate ($r^2 = 0.25$, $P = 0.02$, $n=66$, Figure 8.4a), after accounting for stage of the nesting cycle in both analyses. A linear relationship was suggested between both prey delivery rates and mass delivery rate versus brood size (lack of Fit F-tests were not significant: $P = 0.93$ and $P = 0.71$, respectively). Peregrine Falcons delivered on average 23% ($\pm 7\%$) more prey with each increase in brood size and median mass delivery rates increased 53% ($\pm 12\%$) with each additional chick.

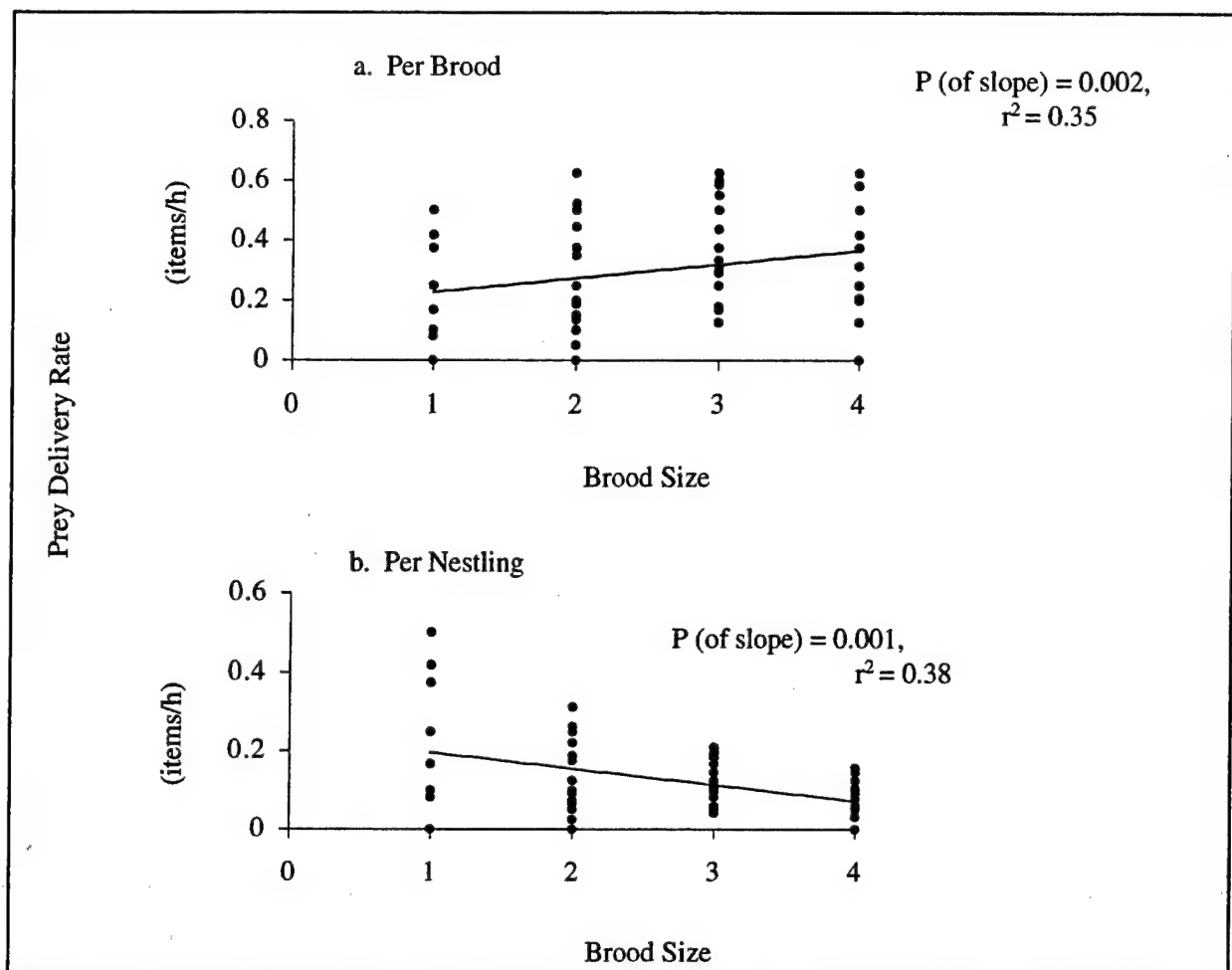


Figure 8.3. Prey delivery rate per brood (a) and per nestling (b) as a function of brood size in *Peregrine Falcons* nesting along the Tanana River, Alaska

Prey Provisioning Per Nestling

Prey delivery rates per nestling declined with increasing brood size, after accounting for stage of the nesting cycle ($P = 0.001$, $r^2 = 37.7$, $n=66$; Figure 8.3b). In contrast, mass delivery rates per nestling did not change appreciably with increasing brood size (Figure 8.4b). Median prey delivery rate per nestling declined 8% ($\pm 6\%$; Figure 8.3b) with each additional nestling. In contrast, the slope of the regression of mass delivery rate per nestling on brood size did not differ from zero, after accounting for nesting stage (2-sided test, $P > 0.5$; Figure 8.4b). Consequently, breeding pairs did not compensate for larger broods by proportionately increasing the rate of prey delivery, but instead increased the size of prey delivered.

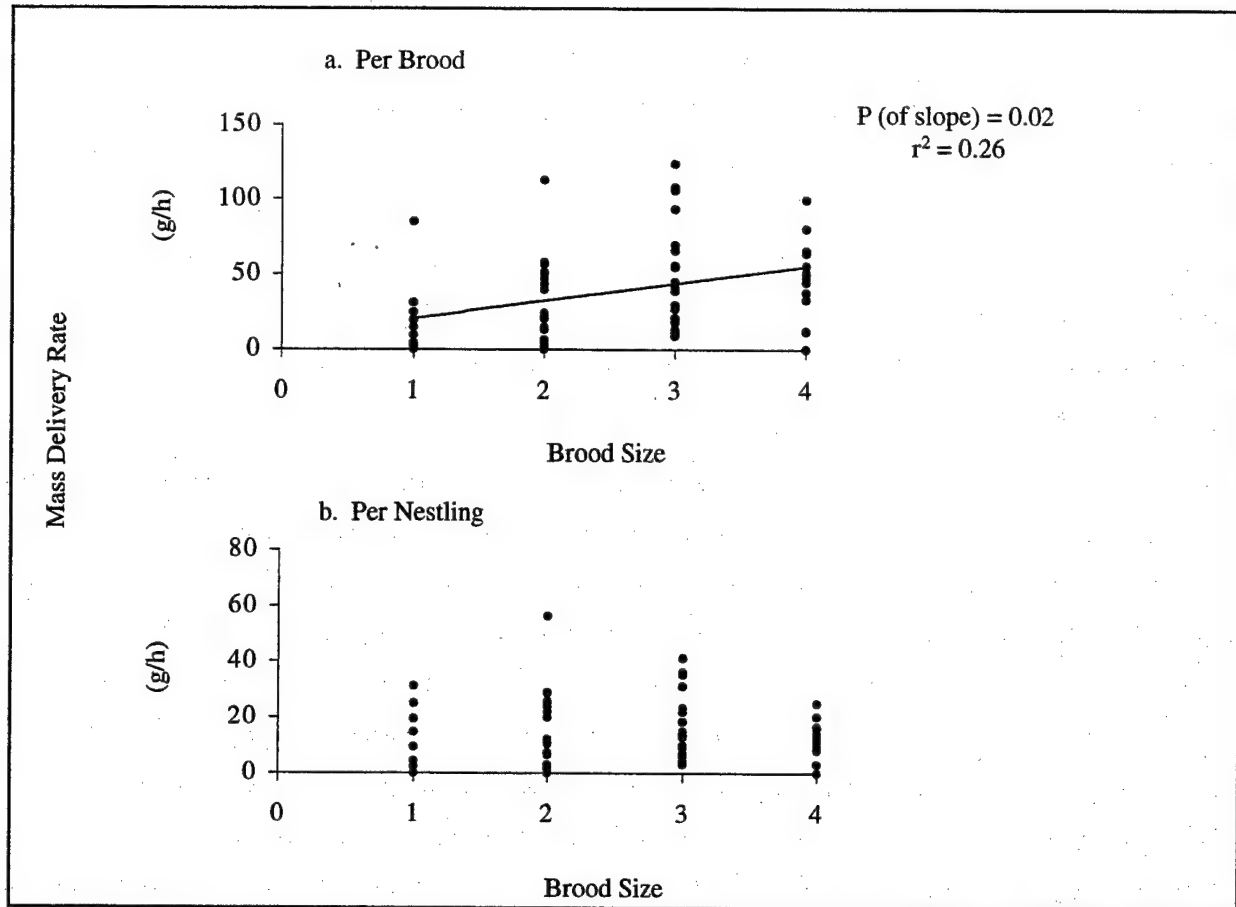


Figure 8.4. *Estimated mass delivery rate per brood (a) and per nestling (b) as a function of brood size in Peregrine Falcons nesting along the Tanana River, Alaska*

DISCUSSION

Our results are consistent with the hypothesis that parents must work harder to provide for larger broods. Pairs with larger broods had higher prey delivery rates (Figure 8.3a), and higher mass delivery rates, after accounting for stage of the nesting cycle (Figure 8.4a). Per nestling prey delivery rates declined with increasing brood size, however, indicating that parents did not fully compensate for larger broods by capturing more prey (Figure 8.3b). Additionally, we found no relationship between per nestling mass delivery rates and brood size (Fig 8.5b). Prey delivery rates per nestling declined with increasing broods size; thus, to maintain constant mass delivery rates per nestling across brood sizes, parents of larger broods must have compensated for lower per nestling prey delivery rates by delivering larger prey on average. In support of this interpretation, average mass increased with brood size (Figure 8.1), and parents of small broods rarely delivered large items. Consequently, different brood sizes were associated with different parental foraging strategies.

We found evidence for a positive relationship between time away from the nest prior to delivery and size of prey delivered (Figure 8.2). Time away from the nest could be time spent preening, sleeping, bathing, feeding itself, or foraging for nestlings, however, if we suppose time away from the nest is proportional to distance traveled while foraging, then the prediction of optimal foraging theory that prey size increases with distance traveled (Schoener 1979) was supported. Parent falcons routinely delivered swallows (*Tachycineta* spp. or *Hirundo* spp.; Table 8.1) that were breeding on the nest cliffs, whereas ducks and grebes were delivered infrequently and were never observed being captured within view of the nest. Nevertheless, ducks and grebes comprised the majority of mass delivered to nestlings, in brood sizes greater than one.

Although time away prior to a delivery and prey size were significantly correlated, much of the variability in time away was not explained. This is likely because many other variables, such as hunger level of brood (Tinbergen and Drent 1980, Steidl 1995), prey availability (Hunter et al. 1988, Meese and Fuller 1989, Rosenfield et al. 1995), prey handling time (Beissinger 1983), foraging efficiency (Winkler and Allen 1995), and weather conditions (Steidl 1995) affected time away prior to delivery. Generally, with constant mass delivery rates the relationship between prey delivery rate and average prey size is inverse, i.e., the time required to retrieve a given mass of prey in many smaller prey captured right at the nest may be greater than the time required to retrieve the equivalent mass of prey in a single large item. Another factor that likely influenced time away from the nest prior to delivery was time spent performing activities other than foraging for nestlings, such as preening, sleeping, bathing, or feeding itself.

Theory suggests that raising the maximum possible number of young causes reductions in parental survival, and thus natural brood sizes are lower than maximum to optimize future survival and maximize lifetime reproductive output of adults (Dijkstra 1990). Deerenberg et al. (1995) demonstrated a direct relationship between increased individual work rate in parents with enlarged broods and local survival rate among European Kestrels. They proposed that an optimal work rate may be a proximate control mechanism for brood size, because high work rates may entail physiological weakening, leading to lower survival rates. Nur (1984, 1987) demonstrated that per nestling provisioning rates in Blue Tits decrease with increasing brood size, producing a concave curve. The decline in per nestling provisioning rates is predicted because it does not maximize fitness to provide each nestling in large broods proportionally, given the energetic costs of increased provisioning rates.

Per nestling mass delivery rates, unlike per nestling prey delivery rates were constant across the range of natural brood sizes seen in this study. One possible explanation for constant per nestling mass delivery rates, regardless of brood size, is that parents of smaller broods were working far below maximum sustained working capacity (Dijkstra et al. 1990, Stearns 1992 for a review). This, in turn, could be

because prey were readily available and easy to acquire. An alternative explanation is that pairs with larger broods were better providers and able to regularly kill larger prey and transport it to the nest.

To raise large broods, parents must be efficient hunters to capture and deliver prey at adequate provisioning rates, and they need to maintain a work rate that does not impinge excessively on their future survival and thus reduce lifetime reproductive output (Deerenberg et al. 1995). If natural brood size is an indication of optimal workload per pair, then brood size may reflect parental foraging efficiency. In general, we observed more prey and larger prey delivered to larger broods. Larger prey were related to longer periods away from the nest area prior to delivery perhaps due to a positive relationship between time away and distance traveled. In natural broods, we found parents had equal provisioning rates per nestling regardless of brood size, presumably maximizing both their present and future reproductive output. Distinguishing between parental hunting efficiency and prey availability as they influence prey provisioning rates will be essential to test foraging theory as it relates to Peregrine Falcons feeding young.

ACKNOWLEDGEMENTS

Many people contributed to successful completion of this project. Lt. Col. Robert Kull, and Captain Mike Carter directed funds from the US Air Force. Peter Bente (Alaska Dept. of Fish and Game (ADF&G)) readily shared his extensive knowledge and experience about Peregrine Falcons and the Tanana River. Skip Ambrose (US Fish and Wildlife Service), and Bob Ritchie and Steve Murphy (ABR, inc.) offered important information and recommendations regarding the study design, literature, and field work. Mike Collopy and Dan Schaffer (Oregon State University) gave valuable advice. Bob Schults, Bob Fry, and Hank Tim of the Tetlin National Wildlife Refuge donated time and equipment and Steve Debois and Dave Davenport of Delta ADF&G provided logistical support. Norma Mosso, Judy Romans, and Joy Huber of the Alaska Cooperative Fish and Wildlife Research Unit in the Department of Biology and Wildlife, University of Alaska-Fairbanks, and others from the Department of Fisheries and Wildlife, Oregon State University provided technical support. The project would not have been possible without the dedicated observations by field assistants: Kurt and Nicole Lockwood, Steve Bethune, John Shook, Matt Kopec, Carmen Thomas, Renee Crane, Nate Chelgren, Paul Berry, Dan Cariveau, Gwyllim Blackburn, David Freed, Jay Kolbe, Jochen Mueller, and Jesse Bopp. We extend many thanks to Julian Fischer, Bob Steidl, and Carol McIntyr for their careful review of the manuscript.

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CHAPTER 9

EFFECTS OF JET AIRCRAFT OVERFLIGHTS ON NEST ATTENDANCE, TIME-ACTIVITY BUDGETS, AND NESTLING PROVISIONING RATES OF PEREGRINE FALCONS

Angela G. Palmer, Dana L. Nordmeyer Elmore, & Daniel D. Roby

ABSTRACT

We examined the effects of low-altitude jet aircraft overflights on nest attendance, time-activity budgets, and provisioning rates of Peregrine Falcons (*Falco peregrinus*) breeding along the Tanana River, Alaska in 1995, 1996, and 1997. Subtle changes in these parameters could potentially lead to insidious impacts on nesting success. Nest attendance and time-activity budgets of Peregrine Falcons during periods of overflights differed from those of Peregrines at reference nests (nests rarely overflown). Differences depended on stage of the nesting cycle and gender. During the incubation/brooding stages of the nesting cycle, males attended the nest ledge less when overflights occurred than did males from reference nests. Females apparently compensated for low male ledge attendance by attending the ledge more during overflown periods compared to females from reference nests. Additionally, while females were still brooding nestlings, they were less likely to be absent from the nest area during periods when overflights occurred than females from reference nests. During late nestling-rearing, however, females perched in the nest area less during periods when overflights occurred than females from reference nests. Although we found differences in nest attendance and time-activity budgets between overflown and reference nests, we did not observe differences between periods with overflights and periods without overflights at the same nests. Nor did we detect a relationship between nest attendance and the number of overflights to occur within a given time period, the cumulative number of above threshold noise events at each nest, or the average sound exposure level of overflights. Furthermore, we found no evidence that nestling provisioning rates were affected by overflights.

INTRODUCTION

Human disturbance of wildlife is an increasing concern as human activities expand into wilderness areas. The United States Air Force (USAF) maintains low-altitude Military Training Routes (MTRs) and Military Operations Areas (MOAs) in areas of sparse human settlement in Interior Alaska. Residents and resource management agencies have voiced concern regarding the potential effects of low-altitude jet aircraft overflights on wildlife (Galdwin et al. 1987). As a result of these concerns, in combination with requirements of the National Environmental Policy Act (NEPA) (1969) and the Endangered Species Act (ESA) (1973), the USAF sponsored several research projects to document the effects of aircraft activity on wildlife populations. One taxonomic group of concern was raptors (Falconiformes).

Raptors were of particular concern to wildlife management agencies for several reasons. First, as higher order consumers, they serve as indicators of ecosystem health and general environmental conditions (Newton 1979). Second, many raptor populations have experienced dramatic declines in the last 40 years, leaving some species [e.g., Peregrine Falcons (*Falco peregrinus*) and Bald Eagles (*Haliaeetus leucocephalus*)] threatened with extinction (Hickey 1969, Bird 1983)]. Finally, raptors are sensitive to human disturbance during nesting (Fyfe and Olendorff 1976, Steenhof and Kochert 1982, Steidl 1995). Steidl (1995) found that prey consumption rates by Bald Eagle nestlings decreased with proximity of human recreational activities. It is widely accepted that birds are sensitive to disturbance during particular periods of the nesting cycle. In raptors these periods include early incubation, early nestling-rearing, and early fledging (Fyfe and Olendorff 1976); yet few studies have examined the effects of overflights at these times (Awbrey and Bowles 1990).

Some responses by nesting raptors to aircraft overflights are overt, such as attack or panic flights (Fyfe and Olendorff 1976), while other responses may be subtle and more difficult to detect. Disturbance may result in changes in parental behavior and care of progeny that ultimately affect nesting success as much or more than immediate responses. Historical research on Peregrine Falcons in Alaska has focused on reproductive parameters and population status (Cade 1960; White 1969; Ambrose et al. 1988; Wright and Bente 1999). However subtle, longer term responses to disturbances could lead to insidious impacts on nesting success, such as reallocation of time to nest attendance and various breeding activities, and declines in the rate at which parents provision their young. Ritchie (1987) observed that 13% of behavioral reactions by nesting Peregrine Falcons to helicopters were moderate, and 3% were severe, however sample sizes were small (five nests in two years of study). Few other studies have examined these types of responses by nesting raptors to potential disturbance.

As part of a larger study on the effects of jet overflights on the behavior and reproduction of raptors, we studied Peregrine Falcons to investigate effects of overflights on several components of parental care. These included nest attendance (amount of time parents are near the nest), time-activity budgets (amount of time parents allocate to various activities), and nestling provisioning rates (the rate at which parents deliver food to young). If nest attendance and behavior of adult Peregrine Falcons are influenced by low-altitude jet overflights, we would expect the time-activity budgets of falcons to differ between periods immediately following overflights and periods when no overflights occur, and between nests that are exposed to overflights and those that are not. Additionally, because stage of the nesting cycle plays a prominent role in falcon

breeding behavior, we would predict that behavioral responses to overflights would change as the nesting cycle progresses. Finally, if overflights affect behavior, we would expect a higher frequency and/or intensity of overflights to lead to more pronounced changes in allocation of time to various activities by breeding Peregrine Falcons.

In addition to nest attendance and time-activity budgets, another important aspect of parental care is nestling provisioning rates. If overflights inhibit Peregrine Falcons from either hunting or delivering prey to young, then we would expect nestling provisioning rates to be lower during periods following overflights than during periods when no overflights occurred, and lower at nests that were exposed to overflights compared to nests that were not. Acquiring larger prey items requires longer hunting forays further from nest sites (Schoener 1979); thus, if overflights cause falcons to remain closer to their nests, their ability to provide larger prey items may be reduced. Finally, we would expect a negative correlation between number of overflights and prey provisioning rates.

METHODS

Study Area

The study area encompassed a 250-km stretch of the Tanana River between Tok and Fairbanks (from 63° 8' N, 143° 36' W to 64° 18' N, 148° 45' W; Figure 9.1). In 1995 the study area extended from Tanacross to Sawmill, an approximately 110-km stretch of river, and included two MTRs that crossed the river. Low-altitude military jet overflights were permitted without Federal Aviation Administration clearance in the MTRs. Thirteen active Peregrine Falcon nest sites were found along this stretch of the river. Of these, 9 afforded adequate visibility for observations and 4 of these were located in MTRs and subjected to low-altitude overflights. In 1996 and 1997, we included an additional 65-km section of the river from Delta to Salcha, which included an additional MTR. A total of 19 and 21 active nests were located in 1996 and 1997, respectively, along both stretches of river. In both 1996 and 1997, we observed 6 nests in the upper stretch and 4 nests in the lower stretch. Five and 7 of these 10 observed nests were exposed to overflights and within MTRs in 1996 and 1997, respectively. Two nests that were located within an MTR and were overflown in 1995 and 1997 were not overflown in 1996.

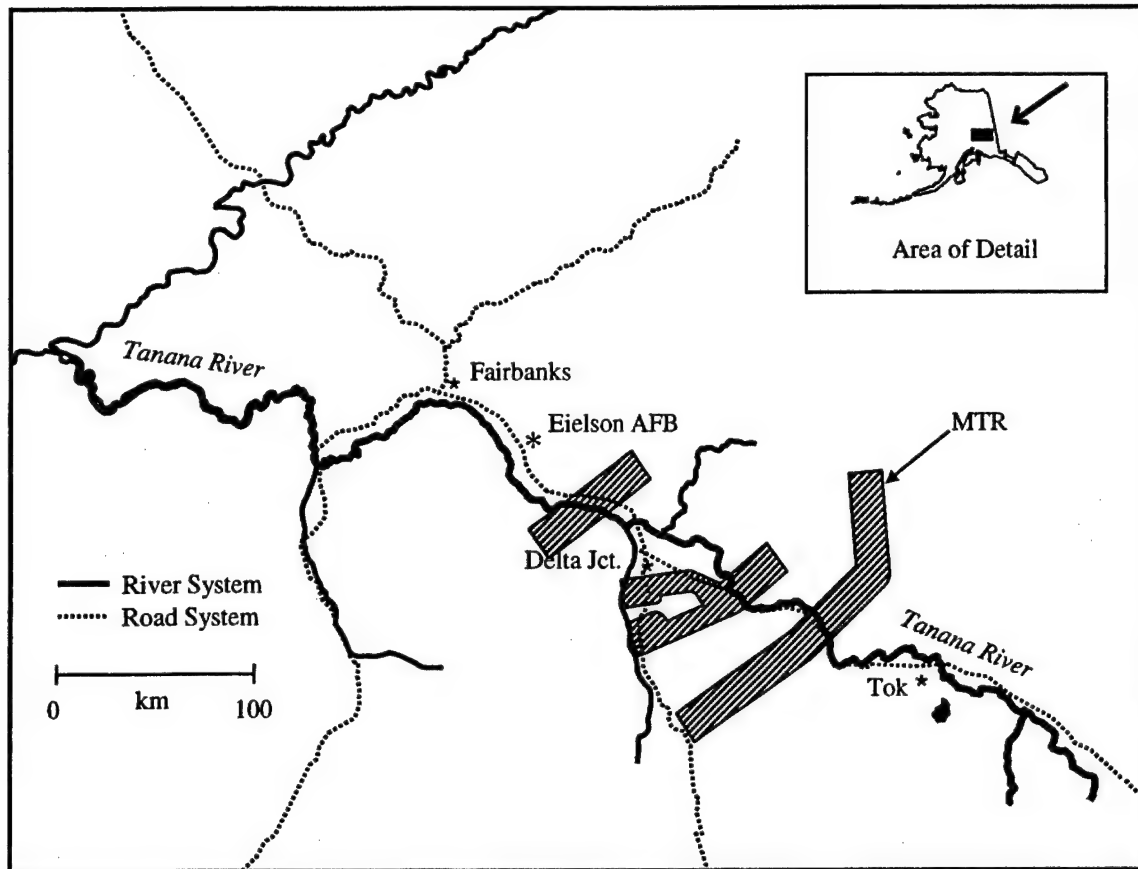


Figure 9.1 Study area along a 250-km stretch of the Tanana River between Tok and Fairbanks, Alaska.

Nests were situated on bluffs overlooking the river. We selected nests for observation based on access to observation sites opposite cliffs and visibility of the nest ledge from the observation sites. Observations were initiated each year as soon as it was safe to travel on the river after ice break-up in mid-May, and continued until the young had fledged and left the area of the nest (late August/early September). A crew of two to four observers recorded data at each Peregrine Falcon nest and two separate crews were in the field throughout each season.

Overflights

The 11th Air Force provided jet aircraft overflights directed at Peregrine Falcon nests that were located in the MTRs. We provided the Air Force with the latitude and longitude of nests, and marked their locations on USGS topographic maps and photographs. We coordinated with the Air Force to schedule overflights during periods when field crews were present and recording observations. The Air Force was able to provide the majority of overflights to nests during three 2.5-week periods each year. Overflights were less likely to occur during the interim periods

because of major training exercises known as Cope Thunder. The first overflight period in each year coincided with incubation, the second with mid to late nestling-rearing, and the third with post-fledging. In 1996 and 1997, the proximity of overflights to active nests was enhanced by Forward Air Controllers (FACs) from the 3rd ASOS at Ft. Wainwright, who joined field crews on the ground.

Animal Noise Monitors (ANMs), which measure several noise dose variables, including sound exposure level (SEL), were deployed on the cliffs near each active nest ledge or scrape to measure noise dose (two ANMs were deployed at each nest within MTRs and one at each nest outside MTRs). The ANMs had the capacity to store 2000 sound profiles of noise events that occurred over a minimum dB level. This threshold level was set at 85 dB for all ANMs. Noise events were only recorded if they exceeded 2 seconds and were less than 2 minutes duration.

We categorized each nest each year as either overflown or reference. Overflown nests were those located within MTRs and exposed to a minimum of 7 overflights that exceeded the 85 dB threshold per season (see Chapter 3 for discussion of overflight criteria). In addition, we classified as an overflight any military jet or helicopter that was ≤ 300 m (1000 ft) in altitude above a nest and ≤ 400 m (1300 ft) lateral distance from a nest during our observations. This is equivalent to a 500 m slant distance, where slant distance is the closest distance from aircraft to nest. Eighty-five percent of noise events detected by ANMs when observers were present had slant distances of ≤ 500 m. Overflown nests received up to 28 observed overflights spread throughout a single breeding season (Table 9.1). In 1995, a maximum of 6 additional noise events per nest were recorded by ANMs when observers were not present (Table 9.1). In 1996 and 1997, an average of 17 additional noise events were recorded by ANMs when observers were not present (Table 9.1), due mostly to the proximity of the new MTR to Eielson Air Force Base. These numbers are likely accurate for jet overflights, but underestimate the number of helicopter overflights. Due to their sound profiles, helicopter noise events were undetected in some instances.

Table 9.1 *The number of overflights^a that overflown^b and reference^c nests were exposed to in 1995, 1996, and 1997. Noise events recorded on Animal Noise Monitors (ANMs) when observers were not present are in parentheses.*

Year/nest type and number	Number of overflights per stage of the nesting cycle			Total	Grand
	Incubation	Nestling- rearing	Post-fledging	Observed	Total
Overflown Nests					
205	11 (2)	8 (0)	no obs.	19	21
221	8 (2)	12 (0)	5 (0)	25	27
281	no obs.	10 (6)	3 (no ANM)	13	19
288	2 (2)	3 (0)	no obs.	5	7
Reference Nests					
243	0 (1)	0 (1)	0 (no ANM)	0	2
247	0 (0)	0 (1)	no obs.(no ANM)	0	1
258	no obs. (0)	0 (1)	no obs.(no ANM)	0	1
269	no obs. (0)	0 (1)	0 (no ANM)	0	1
299	no obs. (4)	0 (1)	no obs. (no ANM)	0	5

Table 9.1 (Continued)

Year/nest type and number	Number of overflights per stage of the nesting cycle			Total	Grand
	Incubation	Nestling- rearing	Post-fledging	Observed	Total
Overflowed Nests					
280.5	18 (9)	4 (7)	0 (0)	22	38
288.5	1 (4)	23 (11)	4 (1)	28	44
427	9 (12)	4 (20)	15 (2)	28	62
431	2 (14)	nest failure	-	-	16
438.6	1 (12)	15 (14)	4 (0)	20	46
Reference Nests					
205	0 (0)	nest failure	-	0	0
221	0 (1)	0 (1)	0 (0)	2	2
258	no obs. (no ANM)	no obs. (no ANM)	0	0	0
269.5	0 (0)	0 (0)	0 (0)	0	0
379*	0 (5)	0 (7)	2 (13)	2	27

Table 9.1 (Continued).

Year/nest type and number	Number of overflights per stage of the nesting cycle			Total	Grand
1997	Incubation	Nestling- rearing	Post-fledging	Observed	Total
Overflown Nests					
205 1 (0)		1 (4)	0 (1)	2	7
221 3 (2)		2 (8)	0 (2)	5	17
280.5 24 (2)		0 (0)	2 (4)	26	32
288.5 7 (9)		2 (32)	0 (4)	9	54
427 0 (21)		0 (34)	12 (15)	12	82
431 0 (15)		6 (47)	17 (12)	23	97
436 10 (23)		nest failure	nest failure	10	33
Reference Nests					
1 (2)		0 (6)	0 (2)	1	11
181.7*					
269.5 0 (4)		0 (0)	0 (1)	0	5
379* 0 (11)		0 (1)	0 (0)	0	12

^a Overflights were classified as any military jet or helicopter that came within a 500 m slant distance of the nest, where slant distance is the closest distance from the aircraft to the nest.

^b Overflown nests are those that were exposed to a minimum of 7 overflights above the 85 dB threshold during a given breeding season.

^c Reference nests are those that were exposed to no more than 5 noise events above the 85 dB threshold during a given breeding season.

* These reference nests were excluded from analyses due to the number of above threshold noise events recorded by ANMs when observers were absent.

Reference nests were those that received a maximum of 5 above-threshold noise events, either in the presence or absence of observers (Table 9.1). All nests in all years met this criterion, except 3. Nest 379, in both 1996 and 1997 and nest 181.7 in 1997 received greater than 5 noise events detected by ANMs and were thus excluded from the analyses. One reference nest in 1996 did not have an ANM deployed nearby, but was likely not exposed to above-threshold noise events (1) because the location of the nest was remote with respect to MTRs, and (2) the exposure of the closest reference nest (10 km down-river) to above-threshold noise events was nil.

Behavioral Observations

We established observation sites across at least one channel of the river and 300-750 m from nests to permit observation of nest attendance, time-activity budgets, and prey deliveries without disturbing the breeding pair. Observation distance from nests depended on available observation sites and the sensitivity of individual falcons to human presence.

We used binoculars, 15-60 X spotting scopes, and Questar telescopes to aid our observations during 3 stages of the Peregrine Falcon nesting cycle: incubation, nestling-rearing, and post-fledging. We recorded nest attendance and time-activity budgets during incubation and nestling-rearing, and measured prey provisioning rates during nestling-rearing and post-fledging. Of the 9 nests observed in 1995, we observed 4 during incubation, 8 during nestling-rearing, and 4 during post-fledging. In 1996, we conducted observations during incubation, nestling-rearing, and post-fledging at 7 of 10 nests. The other 3 nests were not sampled during all three phases of the nesting cycle because 2 nests failed following incubation and were replaced by one other nest. In 1997, we sampled behavior during all three stages from 8 of 10 nests; of the remaining nests one failed after incubation and was replaced by another nest during nestling-rearing. For analysis, the nestling-rearing phase was further subdivided into three stages, early nestling-rearing (0-10 days post-hatch), mid nestling-rearing (11-24 days), and late nestling-rearing (25-42 days). Stage was determined by the estimated age of the oldest chick based on banding visits to the nest during mid nestling-rearing.

We used Canon L2 Hi-8 mm and Sony CCD-FX430 8 mm video cameras equipped with 250 mm lenses and 2X extenders to record nest attendance, adult behaviors, and prey deliveries during observations. During incubation and nestling-rearing periods, one camera was focused on the nest ledge, while the other was focused on the attending adult. During the post-fledging period, we focused on visible fledglings or adults. Video tapes provided additional data on behavior during times when instantaneous scans were insufficient to describe events. We used tents to

protect gear from inclement weather and as blinds at sites where adults were more sensitive to human presence.

Nest Attendance and Time-Activity Budgets

We used the instantaneous scan method to sample activity (Altmann 1974, Tacha et al. 1985) at one-minute intervals for each adult. Scans contributed data to both nest attendance and time-activity budgets. For nest attendance, we distinguished between attendance at the nest ledge or scrape, attendance in the nest area (within 200 m of the nest ledge), and away from the nest area (greater than 200 m from the nest ledge or scrape, or not observed within the nest area). For time-activity budgets, we recorded adult activity as one of 6 categories (Table 9.2). We categorized birds as "out of sight" for no longer than 5 minutes without confirmation of their location. Adult activity was classified as "unknown", or away from the nest area, if they were not detected within 5 minutes.

Table 9.2 *Activity categories for time-activity budgets of peregrine falcons breeding along the Tanana River, Alaska.*

Activity Categories ^a	Primary Activities
Incubating/ Brooding/ Shading	<u>incubating</u> : prone posture covering eggs <u>out of sight (OS1)</u> : on the nest ledge/scrape, but out of sight, e.g., in a cavity at the nest ledge <u>brooding</u> : covering nestlings, wing may be slightly off to the side <u>shading young</u> : shielding nestlings from direct sunlight
Perching	<u>perching</u> : standing on one or both feet <u>out of sight (OS2)</u> : known to be on nest cliff, but out of sight, e.g, obscured by vegetation or rock outcrop; adults were classified as unknown if their location was not verified after five minutes.
Feeding Self	<u>feeding self</u> : consuming prey
Feeding Young	<u>feeding young</u> : feeding prey to nestlings or known to be feeding young but out of view, possibly in a cavity
Flying	All flight behaviors: <u>flapping</u> : active flight that involves wing flapping

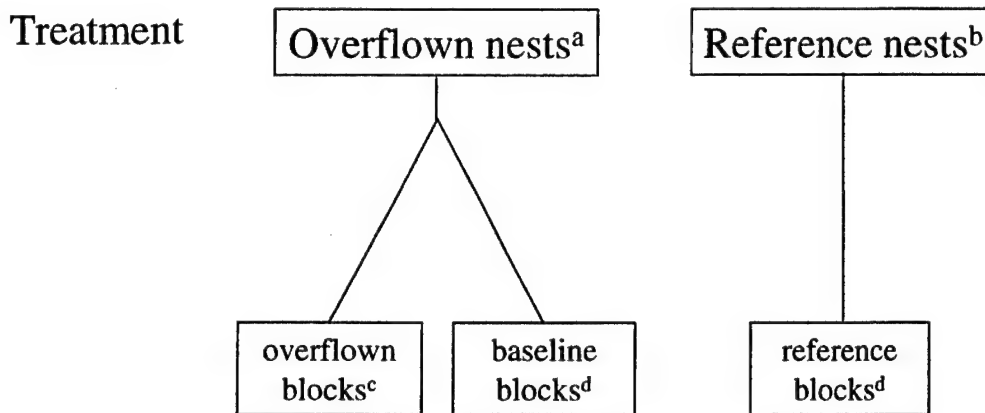
soaring or gliding: passive flight with little to no wing movement
stooping: wings tucked, in downward pursuit of prey from altitude
diving: Aggressive attack on prey or predator

Unknown location unknown: assumed to be away from the nest site in flight foraging or perching

^a Other behaviors (lying: with sternum resting on the ground, walking, and running) occurred less than 1 % of time.

An observation block refers to the group of one-minute scan samples that fell within a 1- to 4-hour time period. We grouped scans in this way to avoid autocorrelation in the data from one-minute scans. We collected behavioral data during 405 observation blocks during incubation and nestling-rearing. Analyses, however, were restricted to the 73 blocks when overflights occurred, 73 baseline blocks, and 78 reference blocks. Baseline and reference blocks were selected to correspond with the same stage of the nesting cycle and time of day as overflight blocks as much as possible; however, observation blocks during mid nestling-rearing were under-represented at reference nests. Additionally, within the 1- to 4-hour range in observation blocks, we truncated the length of baseline and reference blocks so as to match the length of overflown blocks from the same stage of the nesting cycle and time of day. Most overflights occurred between 0800 hrs and 1700 hrs ADT; thus, we also restricted inclusion of data to observation blocks that overlapped this 9-hour period. Observation blocks were discarded if visibility was poor, or if the sex of adults was indeterminant throughout the block.

We compared attendance and time-activity budgets between observation blocks when overflights occurred (overflown blocks) and two types of control observation blocks: 1) from overflown nests when overflights did not occur (baseline blocks) and 2) from reference nests which were not overflown (reference blocks) (Figure 9.2). These two types of controls helped to distinguish between two different types of variability in nesting behavior. Comparisons of behavior between exposed and unexposed nests control for bias from previous exposure to overflights. In contrast, within-nest comparisons (internal controls) compensate directly for behavioral differences among pairs, but may be biased due to previous exposure to overflights.



^a Overflowed nests were those that were exposed to at least 7 noise events that exceeded 85 dB per season.

^b Reference nests were those that were exposed to less than 5 noise events that exceeded 85 dB per season.

^c Overflowed blocks were 1-4 hr blocks of time when overflights occurred.

^d Baseline and Reference blocks were 1-4 hr blocks of time when overflights did not occur.

Figure 9.2 *Study design for detecting effects of jet aircraft overflights on nest attendance, time-activity budgets, and nestling provisioning rates of Peregrine Falcons nesting along the Tanana River, Alaska.*

The beginning of observation blocks was set either by the timing of the day's first overflight or to coincide with three times of day (0800 hrs, 1200 hrs, or 1600 hrs), and were continued for up to four hours. The first overflight to occur after the first 4-hour overflowed block marked the start of the next 4-hour overflowed block. Baseline observation blocks were matched to overflowed blocks either by selecting observations during the four hours preceding an overflight, or from days without overflights that corresponded to the nesting stage and time of day when overflights occurred. In the latter case, blocks began at 0800 hrs, 1200 hrs, or 1600 hrs. Reference blocks also began at 0800 hrs, 1200 hrs, or 1600 hrs. To calculate ledge attendance by each member of the pair we divided the number of minutes the female or male spent at the nest ledge or scrape by the number of minutes in the observation block. We used female plus male ledge attendance as a measure of total ledge attendance by a pair. As with ledge attendance, we measured area attendance of each parent by dividing the number of minutes each parent spent at the nest ledge or in the nest area (within 200 m of the ledge or scrape) by the number of minutes in the observation block. Likewise, we used female plus male area attendance to estimate total area attendance by the pair. The sample unit for time-activity budgets was the number of minutes the parent spent performing a particular activity divided by the total number of minutes per observation block.

Nestling Provisioning Rates

We recorded the number of deliveries, the estimated size class of each item, and the type of prey delivered (identified to species whenever possible). As a measure of provisioning rates, we estimated the mass of prey identified to species using the average body mass of that species in Dunning (1993). For prey that could be identified only to genus or family, we used the mean mass of all the species of that genus or family (Dunning 1993) that regularly occurred in the study area, except in the case of shorebirds, which span a wide range of masses. We classified shorebirds and prey items that could not be identified to species, genus, or family into the following size classes: small (9-50 g), medium (51-200 g), large (201+ g), or unknown, in order to assign them an estimated mass. For shorebirds and prey items that could be identified only to size-class, we used the median mass of all species of that size class known to regularly occur in the study area (30 g, 125 g, and 641 g for small, medium, and large items, respectively). Prey items that were of unknown size-class were categorized as medium-sized prey items. For analysis of prey item size in relation to brood size, we included only those prey items that could be identified at least down to the level of family and classified them as small (9-50 grams), medium (51-200 g), or large (201+ g), based on the above method of mass assignments.

We estimated prey mass delivery rates as the total prey mass delivered during 2-hour observation sessions. Similarly, we calculated prey item delivery rates as the total number of prey items delivered during 2-hour observation sessions, and we calculated average estimated prey size as total prey mass delivered divided by number of prey items delivered. A delivery was defined as any prey item brought to the nest ledge (or directly to post-fledging young) by a parent. Observation sessions were excluded from analyses if poor visibility persisted throughout the session. Nests were treated independently between years.

We compared nestling provisioning rates between 2-hour observation blocks when overflights occurred (overflowed blocks) and two types of control 2-hour observation blocks: 1) from overflowed nests when overflights did not occur (baseline blocks) and 2) from reference nests (reference blocks) (Figure 9.2). We used 2-hour blocks in order to standardize the amount of time used to calculate provisioning rates because Peregrine Falcons have relatively low delivery rates (about once every 2 hours; Cade 1960), and to maximize the number of available overflowed blocks to include in analyses. We collected data during 284 blocks during the nestling-rearing and post-fledging phases, but restricted analyses to 37 overflowed blocks, 37 baseline blocks, and 38 reference blocks.

Due to the timing of overflights, we restricted analyses to observations from 0700 hrs to 2000 hrs ADT. Overflown blocks began with the first overflight of the day. Baseline blocks were matched with overflown blocks either by selecting the observations 2-hours preceding an overflight, or from days without overflights that corresponded to the nesting stage and time of day when overflights occurred. We selected reference blocks from similar stages and times of day as overflown blocks.

Statistical Analyses

We logit transformed ($\log(Y/(1-Y))$) non-normal proportion data and used log transformations on rates to meet the assumptions of statistical tests. When logit transformations were necessary for total nest attendance, we converted total attendance to a true ratio by dividing the number of minutes the female plus the number of minutes the male spent at the nest ledge or scrape, by twice the number of minutes per observation block. Similarly, for total area attendance we divided the number of minutes the female plus the number of minutes the male spent either at the nest ledge or in the nest area (within 200 m of the ledge or scrape), by twice the number of minutes per observation block. Because response variables included many values equal to 0 or 1, we added 0.5 times the minimum value of the response variable to Y for each proportion to avoid zero in the denominator or numerator of the logit transformed term. Although some analyses were performed with transformed data and accounted for variables like stage of the nesting cycle, brood size, and among pair differences, we report arithmetic means and standard errors calculated from raw data.

We tested for differences in nest attendance, time-activity budgets, and nestling provisioning rates between overflown and baseline blocks using analysis of variance (ANOVA) and between overflown and reference blocks using nested ANOVAs. For the latter, nesting pairs were nested within treatment. For nest attendance and frequently performed activities (females incubating, males and females perching, and males unknown), we examined all data combined and separately by stage of the nesting cycle. We restricted ledge attendance analyses to incubation and early nestling-rearing, when eggs and chicks are most dependent on parents for thermoregulation (Cade 1960). For activities that occurred infrequently (less than 25% of the time on average), we used Fisher's Exact tests and Mantel-Haenszel odds ratio tests with continuity correction for small sample sizes and stratified by stage of the nesting cycle. These tests determine if the odds of an activity occurring during overflown blocks versus either baseline or reference blocks was the result of random chance or, alternatively, was more or less likely to occur. We were unable to account for between-pair variability with these tests due to small sample sizes. Infrequent

activities included females unknown (away from nest area), males incubating or brooding, males or females feeding self, males or females feeding young, or males or females flying. For nestling provisioning rates, we controlled for effects of brood size by including brood size in the model as a continuous variable. We assumed independence between years in observations from the same nest site. All statistical differences with a P-value of 0.10 are reported in the results to minimize Type II error, but the p-values are reported for all tests.

We used linear regression to assess the effects on nest attendance and nestling provisioning rates of (1) the number of observed overflights during a given observation block, (2) the cumulative number of overflights (both observed events and above threshold events recorded by ANMs) that particular nests had been exposed to up to and including that observation block (cumulative number of overflights), and (3) the average SEL of detected overflights to occur within each observation block. We also used linear regression to assess the effects of the cumulative number of overflights on nest attendance and nestling provisioning rates.

RESULTS

Nest Attendance

We detected some differences in nest attendance by parent Peregrine Falcons between overflowed and reference observation blocks, but not between overflowed and baseline observation blocks. Male ledge attendance was lower during overflowed blocks than reference blocks, after accounting for among pair variability and stage of the nesting cycle ($F_{1, 101} = 8.06$, $P = 0.008$; Figure 9.3). Total ledge attendance, however, did not differ between overflowed and reference blocks ($F_{1, 101} = 0.32$, $P = 0.58$), after accounting for among pair variability and stage of the nesting cycle. Females apparently compensated for lower male ledge attendance by attending the ledge more during overflowed compared to reference blocks ($F_{1, 101} = 6.32$, $P = 0.022$; Figure 9.3) after accounting for among pair variability and stage of the nesting cycle.

Similarly, the other measure of nest attendance, area attendance, was lower for males during overflowed blocks than reference blocks ($F_{1, 150} = 3.15$, $P = 0.089$), after accounting for stage of the nesting cycle and among pair variability. This difference was most obvious during incubation ($F_{1, 72} = 6.03$, $P = 0.026$; Figure 9.4).

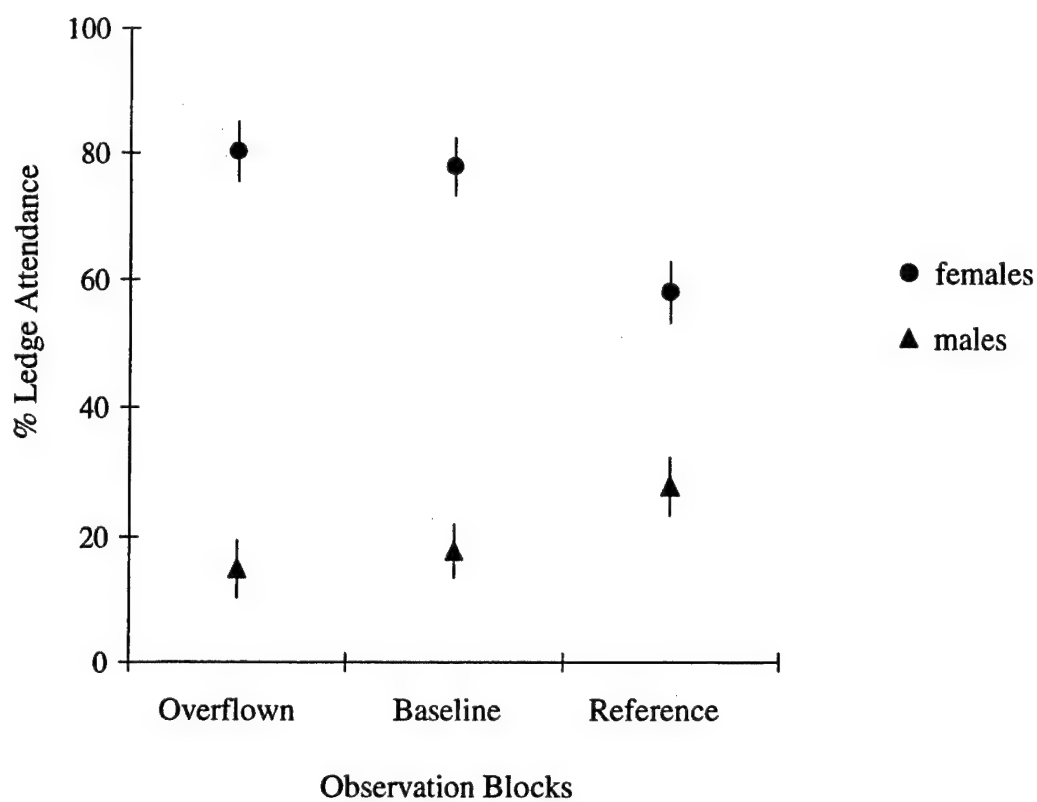


Figure 9.3 *Average ledge attendance (\pm SE) during incubation and early nestling-rearing for overflown, baseline, and reference observation blocks among Peregrine Falcons nesting along the Tanana River, Alaska.*

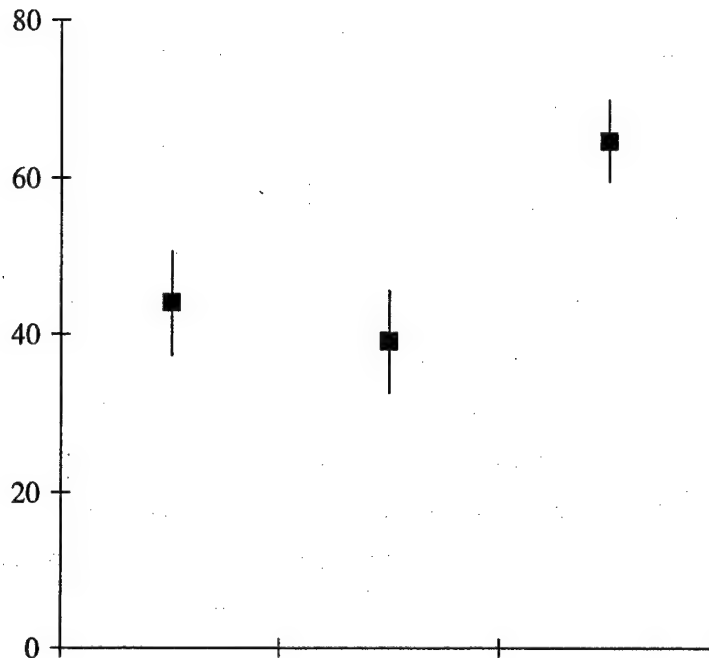


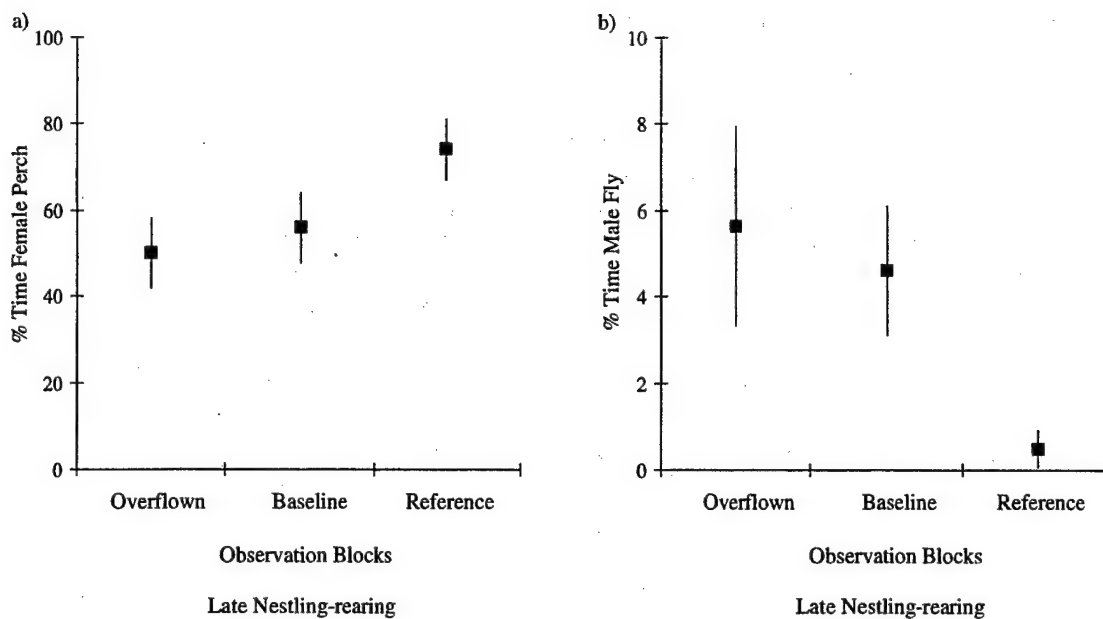
Figure 9.4 *Average male area attendance (+SE) during incubation for overflown, baseline, and reference observation blocks among Peregrine Falcons nesting along the Tanana River, Alaska.*

However, male area attendance did not differ between overflown and baseline observation blocks ($F_{1, 145} = 0.33$, $P = 0.57$). Nor did female area attendance differ between overflown and reference observation blocks ($F_{1, 150} = 0.27$, $P = 0.61$) or between overflown and baseline observation blocks ($F_{1, 145} = 0.11$, $P = 0.74$), after accounting for stage of the nesting cycle and among pair variability. We detected one difference in female area attendance, however, when data were separated by stage of the nesting cycle. Similar to male ledge and area attendance, which were lower for overflown blocks than for reference blocks, female area attendance during late nestling-rearing was lower during overflown blocks than reference blocks ($F_{1, 30} = 4.22$, $P = 0.067$). But, female area attendance was not significantly different between overflown blocks and baseline blocks during late nestling-rearing ($F_{1, 29} = 0.25$, $P = 0.62$). Overall, detected differences in area attendance were small and thus total area attendance did not differ between overflown and reference blocks ($F_{1, 150} = 0.74$, $P = 0.40$). Furthermore, we found no differences in area attendance between overflown blocks and the two types of control blocks during other stages of the nesting cycle for either sex.

While some differences in nest attendance between overflown observation blocks and reference blocks were found, total ledge attendance during either the first half of the nesting cycle (incubation and early nestling-rearing) or the second half of the nesting cycle (mid and late nestling-rearing) was not correlated with the number of overflights that occurred during each overflown block ($P = 0.284$, $df = 42$ and $P = 0.827$, $df = 31$, respectively). Additionally, total ledge attendance during either the first or second half of the nesting cycle was not correlated with average sound exposure level (SEL) from overflights during overflown blocks ($P = 0.330$, $df = 35$, and $P = 0.646$, $df = 26$, respectively). Likewise, total area attendance during the first or second halves of the nesting cycle was not correlated with the number of overflights to occur within observation blocks ($P = 0.149$, $df = 42$, and $P = 0.697$, $df = 31$, respectively). Also, total area attendance during the first or second half of the nesting cycle was not correlated with average SEL from overflights during overflown blocks ($P = 0.428$, $df = 36$, and $P = 0.631$, $df = 26$, respectively). Finally, neither total ledge nor total area attendance was correlated with the cumulative number of overflights that a pair had been exposed to, after accounting for stage of the nesting cycle ($P = 0.168$, $df = 42$, and $P = 0.314$, $df = 74$, respectively).

Time-Activity Budgets

We found little evidence that the incidence of frequently performed activities was influenced by overflights and most differences corresponded with nest attendance activities. Males spent more time performing "unknown" behaviors away from the nest area during overflown blocks than reference blocks, after accounting for variability among pairs and stage of the nesting cycle ($P = 0.066$). This was particularly evident during incubation ($P = 0.014$), and reflected male area attendance (see male area attendance above). There was no difference in the amount of time females spent incubating, or males or females spent perching, after accounting for variability among pairs and stage of the nesting cycle ($P > 0.25$ for all ANOVA tests). When data were analyzed separately by stage, however, females perched less during overflown blocks than reference blocks during incubation and late nestling-rearing, after accounting for among pair variability ($P = 0.048$ and $P = 0.044$ respectively; Figure 9.5a). During incubation, lower perching rates among females were accompanied with higher incubation rates rather, however during late nestling-rearing, lower perching rates were associated with lower attendance rates. Additionally, females incubated more during overflown blocks than reference blocks ($P = 0.0476$), affiliated with higher ledge attendance during incubation by females (see female ledge attendance above).



Figures 9.5a & 9.5b Average percent time a) females perched (\pm SE) and b) males flew (\pm SE) during overflown, baseline, and reference observation blocks during late nestling-rearing among Peregrine Falcons nesting along the Tanana River, Alaska.

We found some evidence that infrequently performed activities differed between overflown blocks and the two types of control blocks (Tables 9.3 and 9.4). Females were less likely to perform “unknown” activities (away from the nest area) during overflown observation blocks than reference observation blocks, after accounting for stage of the nesting cycle ($P = 0.033$, Mantel-Haenszel Test). This effect was most obvious during incubation and early nestling-rearing ($P = 0.031$ and $P = 0.042$, respectively, Fisher’s Exact Test; Figure 9.6), but by late nestling-rearing there was no difference in the incidence of female “unknown” activities between overflown and reference blocks ($P = 0.63$, Fisher’s Exact Test). Similar to attendance results, males were less likely to incubate during overflown than reference blocks ($P = 0.027$, Fisher’s Exact Test). During late nestling-rearing the incidence of flight among males was greater during overflown blocks than reference blocks ($P = 0.024$, Fisher’s Exact Test; Figure 9.5b); however, the 90% confidence interval did not indicate odds different from 1 (0.76 to 2.5). Additionally, this pattern was not apparent throughout the nesting cycle ($P = 0.41$, Mantel-Haenszel Test, Table 9.4). The incidence of other infrequent activities (males or females feeding self, males or females feeding young, or females flying) during overflown blocks was not different than during either

baseline or reference blocks, after accounting for stage of the nesting cycle (Mantel-Haenszel Tests, Tables 9.3 and 9.4).

Table 9.3 *P-values of Fisher's Exact Tests that the difference in odds of females performing a particular activity during overflown vs. non-overflown blocks was not the result of random chance, and Mantel-Haenszel Tests with continuity correction for each activity stratified by stage of the nesting cycle.*

		Activity Category							
Females		Feed Self		Feed Young		Fly		Unknown	
Stage	Test	O vs B ^a	O vs R ^b	O vs B ^a	O vs R ^b	O vs B ^a	O vs R ^b	O vs B ^a	O vs R ^b
Incubation	Exact	all zeros	0.250	n.a. ^c	n.a. ^c	1.000	0.810	0.430	0.031 *
Early Nestling-rearing	Exact	-	0.143	0.620	0.389	1.000	0.640	1.000	0.042 *
Mid Nestling-rearing	Exact	-	0.530	0.412	1.000	0.450	0.257	1.000	1.000
Late Nestling-rearing	Exact	-	1.000	0.402	0.669	1.000	0.600	1.000	0.392
Mantel-Haenszel Test	(χ^2_1)	-	0.15	0.55	0.04	0.11	0.91	0.34	4.55
	P	-	0.70	0.46	0.84	0.74	0.34	0.56	0.033 *

^a O vs B = Overflight block vs Baseline block

^b O vs R = Overflight block vs Reference block

^c n.a. = not applicable

* significant differences $\chi^2 \leq 0.10$

Table 9.4 *P-values of Fisher's Exact Tests that the difference in odds of males performing a particular activity during overflown vs. non-overflown blocks was not the result of random chance, and Mantel-Haenszel Tests for each activity stratified by stage of the nesting cycle.*

		Activity Category							
Males		Feed Self		Feed Young		Fly		Incubate/Brood	
Stage	Test	O vs B ^a	O vs R ^b	O vs B ^a	O vs R ^b	O vs B ^a	O vs R ^b	O vs B ^a	O vs R ^b
Incubation	Exact	1.000	0.444	n.a.	n.a.	1.000	1.000	1.000	0.027*
Early Nestling-rearing	Exact	0.206	zeros	1.000	all zeros	0.637	1.000	0.577	0.666
Mid Nestling-rearing	Exact	1.000	1.000	1.000	-	1.000	0.631	n.a.	n.a.
Late Nestling-rearing	Exact	0.658	1.000	0.603	-	1.000	0.024*	n.a.	n.a.
Mantel-Haenszel Test	(χ^2_1)	0.41	0.24	0.18	-	0.03	0.69	0.21	2.77
	P	0.52	0.62	0.67	-	0.87	0.41	0.65	0.096*

^a O vs B = Overflight block vs Baseline block

^b O vs R = Overflight block vs Reference block

^c n.a. = not applicable

* significant differences $\chi^2 \leq 0.10$

Nestling Provisioning Rates

We found no evidence that overflights affected nestling provisioning rates. Neither prey item delivery rates nor prey mass delivery rates differed between overflown and baseline observation blocks ($F_{1,84} = 0.01$, $P = 0.91$, and $F_{1,84} = 0.01$, $P = 0.96$, respectively), or between overflown and reference observation blocks ($F_{1,85} = 0.43$, $P = 0.52$, and $F_{1,85} = 0.12$, $P = 0.74$, respectively), after accounting for effects of brood size. Additionally, average estimated prey size did not differ between overflown and either baseline ($F_{1,84} = 0.24$, $P = 0.63$) or reference ($F_{1,85} = 0.08$, $P = 0.78$) observation blocks. Furthermore, we did not find a relationship between nestling provisioning rates and either the number of overflights or the average SEL from overflights to occur during overflown blocks. The number of overflights per block (among overflown blocks only) was not significantly correlated with either prey item delivery rate ($P = 0.75$, $df = 42$) or the log of prey mass delivery rate ($P = 0.15$, $df = 42$), after accounting for brood size and stage of the nesting cycle. Moreover, the average SEL of overflights per observation block was not significantly correlated with either prey item delivery rate ($P = 0.91$, $df = 37$) or the log of prey mass delivery rate ($P = 0.62$, $df = 37$), after accounting for effects of brood size and stage of the nesting cycle. Finally, the cumulative number of overflights to which nests were exposed was also not correlated with either prey item delivery rate ($P = 0.93$, $df = 42$) or prey mass delivery rate ($P = 0.35$, $df = 42$), after accounting for brood size and stage of the nesting cycle.

DISCUSSION

Our results provide some support for the hypothesis that low-altitude jet aircraft overflights affect the parental behavior of Peregrine Falcons. Several lines of evidence suggest that Peregrine Falcons exposed to low-altitude jet overflights adjusted their attendance patterns and time-activity budgets compared to reference nests. Males attended the nest ledge significantly less during overflown observation blocks than reference observation blocks, while total ledge attendance did not differ between overflown and reference observation blocks when all data were combined from incubation and early nestling-rearing (Figure 9.3). In contrast to males that attended less during overflown blocks, females balanced ledge attendance, attending more during overflown blocks than reference blocks (Figure 9.3), and were less likely to be away from the nest area during overflown blocks compared with reference blocks during incubation and early nestling-rearing (Figure 9.6)

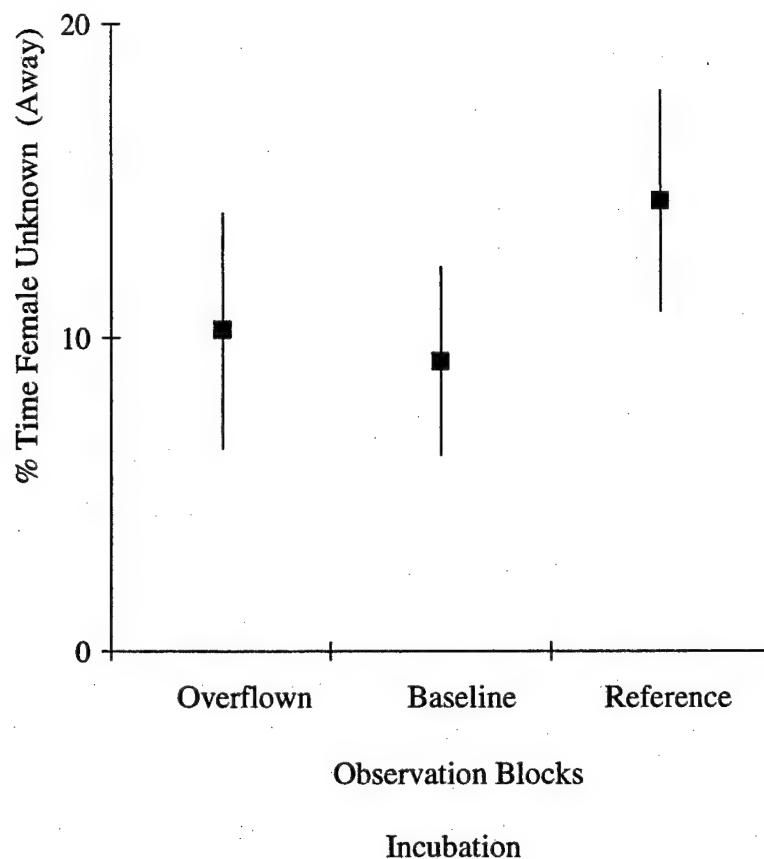


Figure 9.6 Average percent time females were “unknown” (away from nest area; \pm SE) during overflown, baseline, and reference observation blocks during incubation among Peregrine Falcons nesting along the Tanana River, Alaska.

The opposite effect was observed during late nestling-rearing, when females attended the nest area less and perched less during overflown blocks compared to reference blocks (Figure 9.5a). Similarly, males during late nestling-rearing were more likely to fly during overflown blocks than reference blocks (Figure 9.5b). Thus, Peregrine Falcon nest attendance and time-activity budgets differed during periods of overflights compared with reference nests, but differences depended on stage of the nesting cycle and gender, and were not detected in comparisons between overflown and baseline blocks.

Among birds with bi-parental care, males generally allocate time and energy toward nest activities at a more constant rate through the course of the nesting cycle than females, whose time and energy allocated toward attending eggs and young during incubation and early nestling-rearing stages generally far exceed that of males and then shift to equal or lower attendance and

provisioning rates compared with males following mid nestling-rearing (Trivers 1972, Collopy 1984). Decreased ledge attendance during overflown blocks compared with reference blocks early in the nesting cycle suggests that males were less likely to brood eggs or chicks during times of overflight disturbance, apparently forcing females to spend more time on these activities. Alternatively, females may have been less inclined to allow males to relieve them of incubation or brooding duties during overflight disturbance. This is consistent with results from Nordmeyer (unpubl. ms. 1999), who found that the incidence of flight reactions in response to overflights was much higher in males than females and was related to stage of the nesting cycle. Females at overflown nests sat tighter on eggs and young and remained closer to the nest than those at reference nests, apparently in response to greater perceived threat. Other studies found early nestling-rearing to be a stage when raptors are generally more sensitive to disturbance due to the high dependence of young on parents for defense and thermoregulation (Fyfe and Olendorff 1976).

Later in the season, differences in responses between males and females were less obvious, and differed from effects observed early in the season. During late nestling-rearing, females spent less time perching and attending the nest area, and males were more likely to fly during periods with overflights (Fig 9.5). This suggests avoidance of the nest area during periods of overflights late in the season, compared with reference nests. During late nestling-rearing, when chicks can thermoregulate on their own, parents may have been inclined to avoid the nest area during periods of overflights, while not sensing a threat to their offspring from overflights. Immediate behavioral reactions by Peregrine Falcons to jet overflights rarely mimicked behavior typical of nest defense towards potential predators (Nordmeyer unpubl. ms. 1999); thus, it is unlikely that Peregrine Falcons perceived overflights as a threat to their offspring. This might explain why we observed avoidance responses to overflights rather than increased attendance for defensive purposes with progression of the nesting cycle. Many studies suggest nest defense towards potential predators increases late in the nesting cycle (Trivers 1972, Dawkins and Carlisle 1976, Knight and Temple 1986).

Although we found differences in nest attendance and time-activity budgets between overflown and reference nests, we did not detect differences between overflown and baseline blocks within the same nests. This may be due to a residual effect of overflights on nest attendance and time-activity budgets. Perhaps exposure to overflights caused pairs to alter their activity patterns beyond the length of 4-hour observation blocks. Alternatively, because baseline blocks are not independent from overflown blocks, differences between these types of blocks may be more

difficult to detect. Additionally, we did not see a relationship between nest attendance and the number of overflights that occurred in the block, the cumulative number of exposures experienced by each nesting pair, or the average SEL of overflights. Nor did we find evidence that nestling provisioning rates were influenced by low-altitude jet overflights. Also of note is that given the number of statistical tests assessed, one might expect about 5% to reveal positive results based on chance alone. However, our results are compelling because many occurred during incubation and nestling rearing and were more pronounced during these stages when disturbance can be more detrimental to raptors (Fyfe and Olendorff 1976).

Effects of human disturbance on raptor breeding behavior are equivocal. For instance, Platt (1975) subjected gyrfalcons to close approaches by helicopters early in the nesting season and found that none of the 10 nest sites were reoccupied the subsequent year, while prior reoccupancy rates had been around 38%. Andersen et al. (1986) found that an adult male Red-tailed Hawk (*Buteo jamaicensis*) apparently avoided parts of its home range due to ground-based military activities. In contrast, Holthuijzen et al. (1990) found incubation times in Prairie Falcons (*Falco mexicanus*) did not differ between pairs exposed to experimental dynamite blasts and controls, and that nest success and reoccupancy rates did not differ between experimental and control nests. Additionally, Ellis et al. (1991) reported that Peregrine Falcons subjected to low-altitude jet aircraft overflights rarely exhibited direct responses to overflights, usually had minimal responses, and responses were never associated with reproductive failure. Other studies have found minimal changes to time-activity budgets of birds exposed to aircraft or vehicular disturbance (Trimper et al. 1998, Conomy et al. 1998a, Plumpton and Lutz 1993). In particular, Trimper et al. (1998) reported no difference in Osprey (*Pandion haliaetus*) nest attendance between pre- and post-jet overflight periods and control periods of observation. Similar to Trimper et al. (1998), we also did not observe differences between overflown blocks and the two types of control blocks in total ledge attendance or total area attendance. But our results differed from Trimper et al. (1998) in that we found males and females partitioned attendance responsibilities differently in relation to exposure to overflights. It is likely, however, that two different raptor species would have different responses to overflights; Conomy et al. (1998b), for instance, found that American Black Ducks (*Anas rubripes*) habituated to aircraft disturbance with time, while Wood Ducks (*Aix sponsa*) did not.

Although our data provided some support for the hypothesis that low-altitude jet overflights impact patterns of parental behavior at the observed intensity of overflights, other studies have shown relationships between human disturbance and raptor reproductive success. Carpenter

(1993) found that reproductive performance of American Kestrels (*Falco sparverius*) was significantly negatively affected by frequent human disturbances during a year with low prey availability. Additionally, Bednarz (1984) found that breeding Prairie Falcons (*Falco mexicanus*) were absent from an area with heavy mining and blasting activity, yet present in low impact areas, essentially free of mining. Low-altitude jet overflights are a type of potential disturbance that differs from direct human disturbance, and the Peregrine Falcons in the present study likely perceived overflights as a minimal threat to their progeny. Due to their short duration and dissimilarity with natural nest predators, it may take more consecutive overflights to elicit a detectable response (Nordmeyer unpubl. ms.), compared with human disturbance at the nest site.

In this study, we detected subtle effects of jet overflights on Peregrine Falcon parental behavior, but there was no evidence that the magnitude of these effects was sufficient to result in reduced productivity of nesting pairs. Although the intensity and frequency of overflights experienced by some overflown nests in the present study was higher than raptor nests would normally be exposed to in MOAs, the results of this study cannot be extrapolated to nests exposed to higher overflight levels. At present levels, effects were minor and depended on gender and stage of the nesting cycle. In the future, more efforts are needed to assess the roles of habituation and sensitization in the effects of jet aircraft overflights on raptor nesting behavior.

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CHAPTER 10

EFFECTS OF NOISE EXPOSURE FROM JET AIRCRAFT ON NESTING SUCCESS AND PRODUCTIVITY OF PEREGRINE FALCONS IN INTERIOR ALASKA

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ABSTRACT

We examined the relationship between noise exposure from low-flying jet aircraft and nesting success and productivity of Peregrine Falcons in interior Alaska during 1995-1997. Two surveys were conducted each year, the first in late May - early June to locate breeding pairs and active nests and the second in mid-July to check on nesting success and productivity. Surveys in remote "off-river" sites were conducted by helicopter, whereas surveys on the navigable Tanana River were conducted mostly by boat. We monitored 237 nests during the 3-yr study and deployed Animal Noise Monitors (ANMs) at a subsample of 106 nests. The ANMs recorded 2,212 jet aircraft overflights during ~135,000 h of monitoring, with extrapolated exposure levels at individual nests ranging from 0 to 392 overflights during nesting and brood-rearing. We used number of overflights, event duration, and several A-weighted acoustical metrics to test whether noise exposure affected nesting success or productivity. We also used these data to classify different regions of our study area as low, moderate, or high exposure, and these disturbance categories were assigned to nests that were not monitored with ANMs. Failed nests generally had higher levels of exposure to jet aircraft overflights than did successful nests, but these differences were not significant. When the fate of all nests in the study area was evaluated by disturbance categories, there again was a trend for high disturbance areas to have higher rates of nest failure, and this was most pronounced in the off-river sites where nesting success was 80%, 73%, and 63% in the low, moderate, and high disturbance areas, respectively. Models evaluating the effects of noise on productivity also indicated that off-river sites produced slightly fewer young, but again none of these models was significant. Because the off-river population is expanding, whereas the population on the Tanana River is established and relatively stable, these results suggest that disturbance primarily is affecting inexperienced pairs that are prospecting for new nesting territories. Still, productivity of the off-river population equaled or exceeded other monitoring areas in interior Alaska that do not have jet aircraft activity. We conclude, therefore, that population-level effects are not evident for the regional population.

INTRODUCTION

The U.S. Air Force (USAF) regularly conducts training missions in assigned airspace over public and private lands in the United States. Increasing requirements for military training exercises have necessitated the acquisition and maintenance of additional airspace (Asherin and Gladwin 1988). New withdrawals and renewals of existing airspace are subject to the provisions of the National Environmental Policy Act (NEPA), which require that federal agencies consider the environmental effects for any major federal action. One aspect of NEPA documentation that has been problematic for the military planners is predicting the effects of training exercises on wildlife. Although information on the effects of supersonic and low-level subsonic overflights on wildlife has been gathered since the 1960s, definitive research applicable to the NEPA process was lacking (Asherin and Gladwin 1988, Awbrey and Bowles 1990). In the absence of definitive research, worst-case scenarios frequently have been invoked so that decision makers could be confident that they would err on the side of conservatism. Recognizing that the burden of proof lay with the applicant, the USAF initiated a number of programs starting in the late 1980s to better understand the effects of their training operations on wildlife (e.g., Kraussman et al. 1998, Maier et al. 1998, Murphy et al. 1993).

One initiative was directed toward raptors, or birds of prey, because of sensitive and protected populations and perceived vulnerabilities of nesting raptors to aircraft disturbance. The Hubbs Sea World Research Institute was contracted by the USAF in the late 1980s to synthesize the available literature and prepare a preliminary model on the effects of aircraft noise and sonic booms on raptors (Awbrey and Bowles 1990, Bowles et al. 1990). Awbrey and Bowles (1990) reported that no studies to date had demonstrated that raptors were affected catastrophically by aircraft activity, although subtle effects on reproductive output could not be ruled out. Using results generated by nine different studies, Awbrey and Bowles (1990) developed a "straw man model" that was designed to provide a hypothetical worst-case approximation of the relationship between aircraft exposure and nesting success. One of the major goals of our study on Peregrine Falcons was to evaluate the responses of raptors in the wild to jet aircraft so that the model could be tested and refined based on empirical data. In this chapter, we present a quantitative analysis of the relationship between noise exposure from jet aircraft and productivity of nesting Peregrine Falcons in interior Alaska.

Background

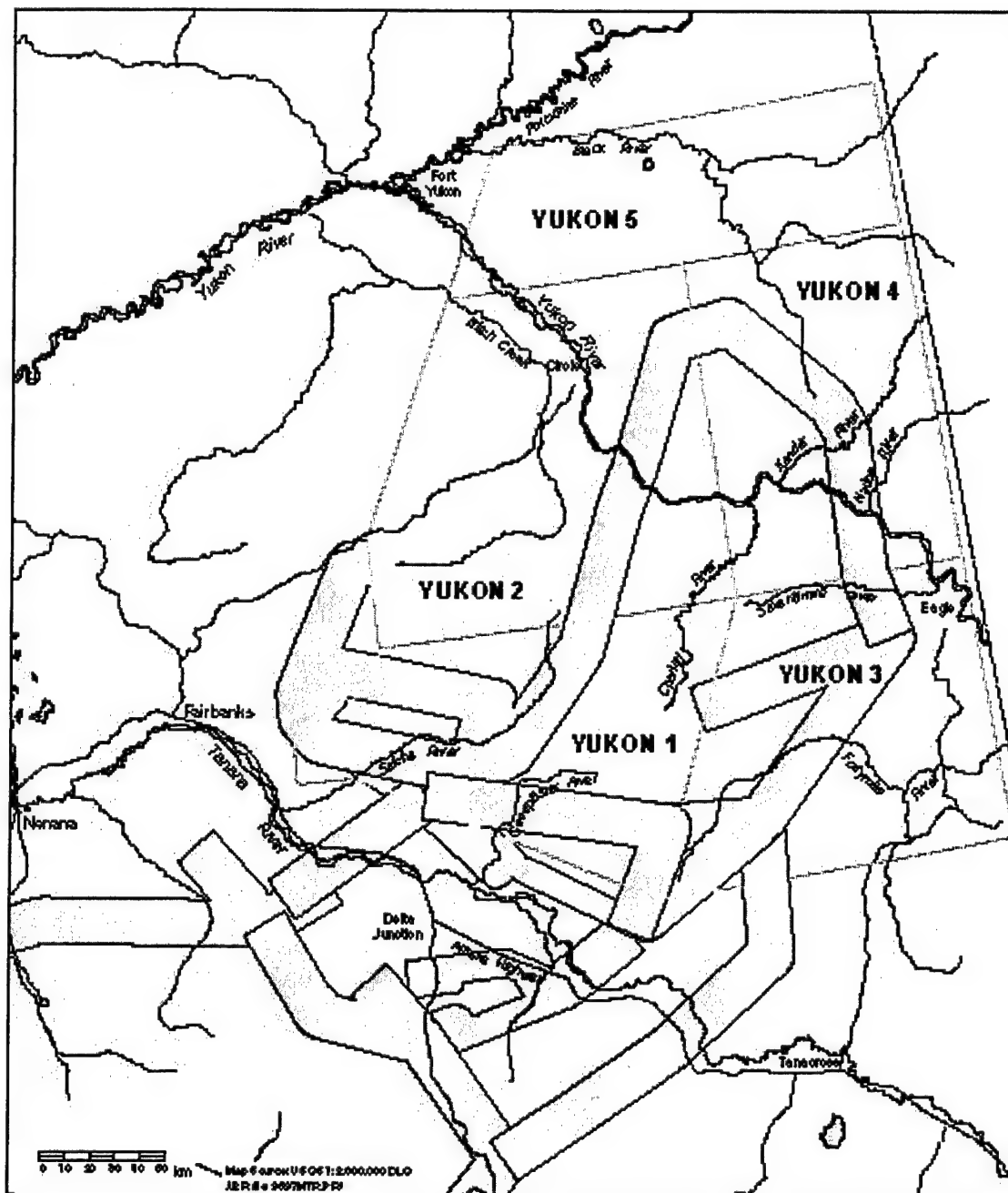
By the early 1970s, the American subspecies of Peregrine Falcon (*Falco peregrinus anatum*) declined dramatically in Alaska due to exposure to pesticides during migration and on their

winter range (Ambrose et al. 1988). Peregrine Falcons were listed as endangered under the Endangered Species Act in 1973, but the American subspecies has recovered during the past 25 years and now is being considered for delisting as an endangered species.

The American subspecies nests primarily along major rivers (e.g., Tanana and Yukon rivers) in the interior of Alaska (Cade 1960). During the recent population expansion, however, a substantial number of breeding pairs have occupied cliffs along small tributaries of these rivers. These "off-river" (i.e., off major drainages) populations generally are less dense than populations on the major rivers, and pairs regularly use isolated montaine tors and rock outcrops for nesting (Kuropat 1986; Ritchie et al. 1998). Few aspects of the life history (e.g., food habits and productivity) of peregrines nesting in off-river sites have been investigated, but these sites may be less optimal than sites along major drainages.

USAF Military Operating Areas (MOAs) and Military Training Routes (MTRs) in interior Alaska encompass many nesting sites used by peregrines, as well as those of a number of other raptor species. In 1993, the U.S. Fish and Wildlife Service (USFWS) initiated surveys to identify off-river nest sites beneath Yukon MOAs 1 and 2 for long-term monitoring (Figure 10.1). In 1994, ABR, Inc. was contracted by the USAF to search for and monitor known off-river sites in these MOAs as part of a survey program managed by the USFWS. In 1995, the study that is the subject of this report was initiated for the USAF by the Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska (UAF) and ABR to assess the effects of jet aircraft overflights on the behavior and productivity of nesting Peregrine Falcons in east-central Alaska. This study was conducted during 1995-1997 in cooperation with the ongoing USFWS monitoring program.

Figure 10.1 Study area along a 250-km stretch of the Tanana River between Tok and Fairbanks, Alaska.



The overall goal of this research project is to determine the effects of low-altitude jet aircraft overflights on reproductive success of Peregrine Falcons nesting in east-central Alaska, as well as those factors that influence the strength of effects. In this chapter, we evaluate the effects of noise from jet aircraft overflights on nesting success and productivity of Peregrine Falcons.

STUDY AREA

The study area for monitoring Peregrine Falcon nest occupancy and productivity included Yukon MOAs 1-5 in east-central Alaska and a portion of the upper Tanana River between the Tetlin Bridge and Nenana (Figure 10.1). No nests in Yukon MOA 5 were used for the noise monitoring experiment, however, and only two nest sites in Yukon MOA 4 were used in 1995. The study area included major drainages, their tributaries, and upland areas in the Yukon-Tanana Uplands and in the Porcupine Plateau between the Yukon and Black rivers. Drainages surveyed included the Tanana, Salcha, Goodpaster, Fortymile, Seventymile, Birch, Charley, Black, Kandik, and Nation (Figure 10.1). Total area for these watersheds is ~62,000 km².

Rounded, even-topped ridges characterize the Yukon-Tanana Uplands with compact, rugged mountains (1200-1500 m in elevation) surmounting this more gentle terrain (Wahrhaftig 1965). The Tanana River portion of the study area includes riparian cliffs of granite and schist that rise from 25 m to 200 m above the outwash plain along the river. Low ridges with gentle slopes and rounded summits (450-750 m in elevation) dominate the Porcupine Plateau; cliff structures generally are limited to the riparian areas. Potential nesting habitats include sheer volcanic and sedimentary cliffs exceeding 200 m in height along the Seventymile River and Birch Creek to isolated volcanic ridges, small granite tors, and silt and schist bluffs rarely exceeding 25 m along tributaries of the Goodpaster and Salcha rivers

METHODS

Nest Monitoring

Off-River Sites

During the early to mid-incubation period in late May and early June 1995-97, we used a helicopter (usually a Hughes 500D) with two observers to visit known and potential Peregrine Falcon nesting sites. We assessed the status of each site with respect to peregrine nesting activity and deployed noise monitors at a subsample of active sites. Standard procedures involved flying along the center of a drainage, then angling toward prospective nest sites when the aircraft was approximately an 0.8-1.6 km horizontal distance from the cliff, before making a slow (30-60 kph) pass of a cliff at a radial distance of 30-100 m from potential nest sites. Multiple passes were made only to inspect ledges where we were certain that no incubating adults were present, to enable us to closely scrutinize ledges or perches for recent falcon use (i.e., fresh whitewash, scrapes, abandoned eggs). Signs of raptor use were noted, including stick nests, ledges, and whitewash.

At sites where an adult was observed, and at those with a history of use by peregrines, the helicopter landed so we could use a spotting scope to assess the status (i.e., occupied, unoccupied, active) of the site. Landing sites were selected based on accessibility for deployment of a noise monitor, landing safety, and to minimize disturbance to the birds. While on the ground, we scrutinized available ledges, identified behaviors that would suggest breeding (e.g., aggressive adults, courtship behaviors, incubating adults), and we searched for suitable places to deploy noise monitors.

While in the helicopter, we recorded all sites with Peregrine Falcons on USGS 1:63,360 maps and an onboard GPS. After surveys, location data were entered on GIS base maps.

Sites were revisited in mid-July during the nestling period. A helicopter with two observers flew by known nest sites to count young and to inspect the condition of the site. Following similar precautions as those taken during the first site visit, the helicopter landed near each site for ground visits to the nests and to recover noise monitors. Nest sites were approached on foot to band and measure young, collect prey remains, and recover noise monitors. Ropes and climbing gear were used to reach nests on steep cliff faces.

In addition to sites that were surveyed, both during incubation and the nestling period, we acquired data at a number of other sites that we only could visit once. Only data on nest occupancy are included from these single survey sites.

Tanana River Sites

Peregrine Falcon nesting sites along the Tanana River were visited in mid-May by boat. Cooperating with the UAF field team, we deployed noise monitors at all active sites selected for behavioral monitoring. We used techniques similar to those used at remote sites to determine the status of each site and to deploy noise monitors.

We revisited each active site in mid-July using an inflatable raft with an outboard engine to determine the fate of each nest, count young, band and measure young, and gather prey remains at study sites monitored by the UAF team. ANMs were retrieved by UAF field personnel in August; thus, nests on the Tanana River typically had more days of noise monitoring than did off-river nests.

Noise Monitoring

Noise data were collected using ANMs. ANMs are all-weather, portable, automatic devices that record a series of noise parameters generated by an intruding source (see Chapter 3). The ANMs specifically were developed to improve the study of noise effects on wildlife by providing the

means to measure the exposure of free-ranging animals to transient noise, such as aircraft overflights.

Once a nest site was determined to be occupied (i.e., at least one member of a pair defending a ledge, or an adult in an incubating posture), a location on the cliff with exposure and elevation characteristics similar to the nest site was selected for ANM deployment. In most cases ANMs were deployed at cliffs where an adult was recorded in an incubating posture. Although we tried to get ANMs close to the active nest (~50 m), we took special care to reduce our disturbance of nesting birds, and, in most cases, we were successful in deploying the monitors without dislodging the incubating bird.

We placed ANMs on a flat, or nearly flat, surface mimicking as closely as possible the physical characteristics of the nest ledge (e.g., slight overhang, wooded side slope, similar elevation and exposure). A 12-inch metal stake was driven into the slope directly beneath the ANM, and the ANM was fastened to the exposed head of the stake with a small locking clamp. After the ANMs were secured, they were initialized and tested to verify that they were working. The location of each ANM was described in a field note book, noted on a photograph along with the nest location, and the site was discretely flagged to facilitate relocation.

The ANMs were programmed to sample all noise events that exceeded 85 dBA for >2 seconds. Recording was terminated when the noise level dropped below 75 dBA. Noise events that lasted >2 minutes were not recorded, because it is unlikely that a jet aircraft overflight would exceed 75 dBA for that duration.

When retrieving the ANMs, we approached the cliff carefully to determine current status and the activity of Peregrine Falcons. We then collected the ANMs, terminated data collection, and recorded the time of recovery, condition of monitors, and whether they appeared to be working (i.e., still had battery charge).

Data Analysis

Nesting Success and Productivity

Each nest was classified as either failed or successful based on whether at least one nestling was raised to banding age (≥ 15 days after hatch). Productivity measures also were calculated based on the number of young in the nest at banding. Although this was 2-3 weeks earlier than fledging, a more common time for assessing productivity of raptors (Steenhof 1987), most monitoring programs in Alaska use number of young at banding because this is the time most productivity surveys occur and it is impractical to revisit nests again after banding. Thus, we

regard our measure of productivity to be a reasonable surrogate for the standard measure and one that allows for comparisons with other monitoring programs in Alaska. We calculated the mean number of young produced for all pairs and for successful pairs only. Mean number of young/total pair is the best measure of productivity for the entire population (Steenhof 1987), and this metric was used in all of our statistical analyses of productivity. Mean number of young/successful pair is an insightful metric for understanding how many nestlings the adults were able to rear given that they were successful.

Effects of Noise on Nesting Success and Productivity

ANM data were downloaded and screened to eliminate records that did not represent jet aircraft overflights. From this screened data set, we calculated summary statistics for each nest based on A-scale noise variables for each valid event. These summary statistics included:

- Number of events - an extrapolated and standardized measure of the number of aircraft overflight events that a breeding pair would experience during the entire nesting season. Calculated as the number of recorded events divided by the time the ANM was active, multiplied by 58 (the number of potential overflight days during the nesting period; note: very few military overflights occur on weekends);
- Event duration - Average (arithmetic) duration of each aircraft overflight;
- L_{MAX} - peak instantaneous decibel level for each event;
- Sound Exposure Level (ASEL) - Total amount of acoustical energy generated during the event period;
- Daily Average SEL - a time averaged (logarithmic) and standardized metric that incorporates both the frequency and magnitude of noise events, which is computed as follows:

$$\text{Daily Average ASEL} = 10\text{LOG} \{1/d * \Sigma (10^{(Lx/10)})\}; \text{ where,}$$

Lx = the sum of all ASEL values for each event over the period of deployment, and d = the number of exposure days (deployment days minus weekends) at each nest during the period of deployment.

Two data sets were used for analyses of the effects of noise on nesting success and productivity of Peregrine Falcons. For the subsample of nests for which there was accompanying noise data, we used the five noise exposure variables described above to test for disturbance effects. We used t-tests to examine whether each of the five noise exposure variables differed between

successful and failed nests. These tests were performed for all ANM nests and separately for Tanana River ANM nests and off-river ANM nests. We also used the same noise exposure variables and geographic stratification to assess the effects of jet aircraft noise on productivity (i.e., number of young). For these analyses, we used simple linear regression to examine dose-response relationships between noise exposure and productivity.

The second data set we used was the larger set of nests with known nest fate and productivity, but not necessarily with accompanying noise data. For these nests, we used the subsample of ANM nests to classify each drainage (or section of a drainage) in each year as having received either high, medium, or low exposure from jet aircraft. This was done by calculating the average number of overflights/day recorded by all ANMs in a particular drainage. Each nest in those drainages then could be assigned a disturbance level even if it had not been monitored with an ANM. Ten off-river nests could not be assigned a disturbance level in this manner because they occurred on drainages that had no ANM nests. For the Tanana River, we calculated the number of flights/day separately for ANM nests in and out of MTRs. Disturbance categories were defined as: low = <0.1 overflights/day, moderate = $0.1-0.5$ overflights/day, and high = >0.5 overflights/day. We used *chi* square goodness-of-fit tests to evaluate whether nesting success varied among low, moderate, and high disturbance nests, and we used an analysis of variance (ANOVA) to assess the effects of disturbance on productivity.

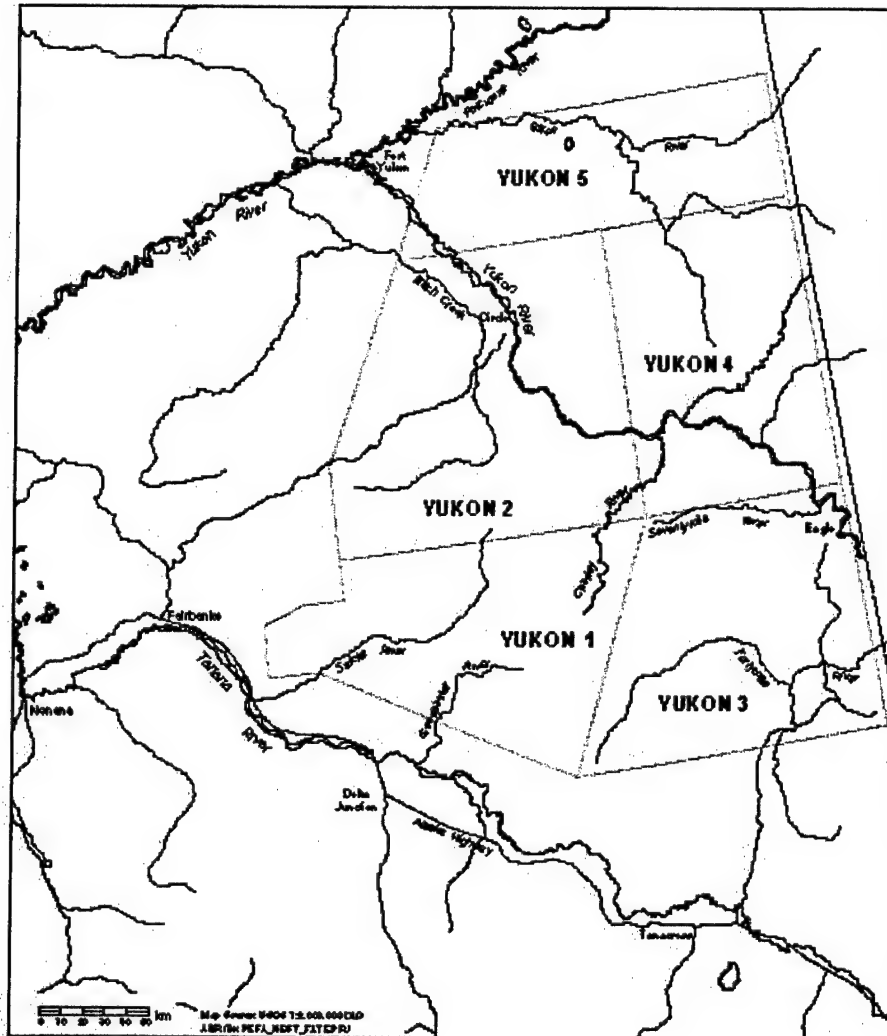
We report *p* values for all statistical tests. Tests with $p \leq 0.05$ are considered significant, tests with $0.05 < p \leq 0.10$ are considered marginally significant, and tests with $p > 0.10$ are considered not significant.

RESULTS

Nesting Success and Productivity

During 1995-97, we acquired nest fate and productivity information at 237 Peregrine Falcon nesting sites (most sites were monitored for multiple years) (Figure 10.2). Some nesting sites were newly discovered during our surveys, whereas others, particularly those on the Tanana River, have long records of occupancy. Sixty-one nest sites were selected for noise monitoring in at least one year of our study. A number of sites were monitored for multiple years; overall, we acquired a sample of 106 nesting attempts with nest fate, productivity, and noise exposure data during this 3-year study.

Figure 10.2 Study design for detecting effects of jet aircraft overflights on nest attendance, time-activity budgets, and nestling provisioning rates of Peregrine Falcons nesting along the Tanana River, Alaska.



Of the 237 nests where nest fate could be determined, 178 (75%) were successful, whereas 59 (25%) failed (Table 10.1). Overall, productivity in the study area during 1995-97 was 1.9 young/total pair and 2.5 young/successful pair. Interannual differences were slight, with the lowest success rate, but the greatest productivity occurring in 1995.

Our subsample of 106 nests with ANM noise data had slightly higher nesting success than did the larger sample: 83 (78%) were successful and 23 (22%) failed (Table 10.1). Productivity for the ANM nests during 1995-97 (2.0 young/total pair and 2.6 young/successful pair) also was greater

than the larger sample. Interannual trends at ANM nests was similar to the larger sample, except that both nesting success and productivity were highest in 1995.

Table 10.1 *Nesting success and productivity of Peregrine Falcons in areas used for military jet aircraft training exercises, east-central Alaska, 1995–1997.*

Sample/ Year	No. Nests	Percent Successful	Mean No. Young/ Total Pair	Mean No. Young/ Successful Pair
All Nests				
1995	58	71%	2.1	2.8
1996	77	77%	1.9	2.4
1997	102	76%	1.9	2.3
Total	237	75%	1.9	2.5
ANM¹ Nests				
1995	33	82%	2.2	2.7
1996	34	71%	1.9	2.7
1997	39	82%	1.9	2.4
Total	106	78%	2.0	2.6
Tanana River				
1995	31	74%	2.3	2.9
1996	24	71%	1.8	2.6
1997	33	85%	2.1	2.5
Total	88	78%	2.1	2.7
Off-river				
1995	27	67%	1.8	2.7
1996	53	79%	1.9	2.4
1997	69	72%	1.6	2.2
Total	149	74%	1.7	2.4

¹ A subsample of the nests were equipped with Animal Noise Monitors (ANM) to record noise during overflights.

Nesting success and productivity of peregrine nests on the Tanana River were higher overall and for all years, except 1996, than at off-river sites (Table 10.1). Thus, the greater nesting success and productivity of nests in the ANM subsample compared to the larger sample of all nests reflects the higher proportion of Tanana River nests in the ANM subsample.

Noise Exposure

During 1995-97, we monitored noise for 134,967 h at 106 nests (mean = 1,273 h or 53 days/ nest; Table 10.2). At these nest sites, the ANMs recorded noise from 2,212 jet aircraft overflights,

with >60% occurring in 1997. The ANM data revealed that nests potentially were overflowed an average of 36 times (range 0-392) during the nesting period and that the average event lasted for ~8.3 sec., with an average peak decibel reading of 104.7 dBA and average SEL of 100.7 dBA. The mean daily average SEL for all nests was 86.3 dBA (range 60 [assigned value to nests with no overflights] to 114.5). Daily average SEL perhaps is our best measure to characterize the overall noise exposure for a given nest, because it integrates both the number of events and the loudness of the events. Thus, we can assume that the nests with the highest daily average SEL were in a regularly used flight path and that the jets typically passed close to the nest. A complete compilation of data from the ANMs is presented in Chapter 3.

Table 10.2 *Number of Animal Noise Monitors deployed, hours of monitoring, and number of jet aircraft overflights at Peregrine Falcon nests in areas used for military jet aircraft training exercises, east-central Alaska, 1995-1997.*

Year	No. of Nests Monitored	Hours of Monitoring	Number of Overflights
1995	33	30,247	268
1996	34	53,322	591
1997	39	51,398	1,353
Total	106	134,967	2,212

Using the ANM data, we classified each drainage in each year as having received either high, medium, or low exposure based on the number of overflights from jet aircraft (Table 10.3). Each nest in those drainages then was assigned a disturbance level even if it had not been monitored with an ANM. Of the 227 nests that were classified in this manner, 59 were in the high disturbance category, 118 were in the moderate category, and 50 were in the low category.

Table 10.3 *Number of active nests, jet aircraft overflights per day, and classification of disturbance by drainage and year, in Military Operations Areas (MOA) and Military Training Routes (MTR), east-central Alaska, 1995–1997.*

MOA/Site	Drainage	1995			1996			1997		
		No. Nests	Flights/Day ¹	Disturbance Class ²	No. Nests	Flights/day	Disturbance Class	No. Nests	Flights/day	Disturbance Class
Yukon 1	Salcha	4	2.5	High	5	0.9	High	6	2.7	High
	Goodpaster	1	0.4	Moderate	4	0.1	Moderate	4	2.4	High
Yukon 2	Upper Birch	5	0.5	Moderate	9	0.9	High	10	0.7	High
	Lower Birch	2	0.3	Moderate	7	0.1	Moderate	5	0	Low
Yukon 3	Seventymile	10	<0.1	Low	10	<0.1	Low	10	<0.1	Low
	Fortymile	3	<0.1	Low	11	<0.1	Low	31	0.2	Moderate
Yukon 4	Kandik	1	0.3	Moderate	-	-	-	-	-	-
	Nation	1	0	Low	-	-	-	-	-	-
In MTR	Tanana	10	0.5	Moderate	10	0.6	High	11	1.0	High
Out of MTR	Tanana	21	0.1	Moderate	14	0.2	Moderate	22	0.3	Moderate
TOTAL		58			75			99		

¹ Overflights per day was calculated from a subsample of nests on each drainage that were equipped with noise monitors.

² Disturbance class low = <0.1 overflights/day; moderate = 0.1 – 0.5 overflights/day; high = >0.5 overflights/day.

Effects of Noise on Nesting Success and Productivity

Nesting Success

We used the data from the ANMs to evaluate whether failed nests were subjected to different noise levels than were successful nests (Table 10.4). For all nests, all noise exposure parameters indicated that failed nests were exposed to more noise than were successful nests. When compared statistically (t-test), however, only potential exposure was marginally significant ($p = 0.097$). For nests on the Tanana River, the trends for the noise exposure variables were not as consistent (e.g., successful nests had higher daily average SEL), but again potential exposure was marginally significant ($p = 0.075$) and indicated that failed nests were overflown more frequently. At off-river nests, the trends again consistently indicated that failed nests were exposed to more aircraft noise; Max SEL and ASEL were both marginally significant ($0.05 < p \leq 0.10$).

Table 10.4 Comparison (t-tests) of jet overflights and noise exposure at successful and failed Peregrine Falcon nests in areas used for military jet aircraft training exercises, east-central Alaska, 1995–1997. Significant results ($p < 0.1$) are depicted in bold-face type.

Sample	Dosage Parameter	Mean		F	p value	n
		Success	Failed			
All nests	Number of overflights ¹	30.99	53.74	2.80	0.097	106
	L _{MAX} ²	98.90	103.87	1.13	0.290	106
	ASEL ³	90.12	92.97	0.67	0.416	106
	Duration of event (sec)	6.41	6.34	0.00	0.957	106
	Day Avg. ASEL ⁴	85.70	88.67	0.64	0.427	106
Tanana River	Number of overflights	23.94	55.45	3.39	0.075	35
	L _{MAX}	104.31	95.50	1.29	0.264	35
	ASEL	94.68	85.27	2.79	0.104	35
	Duration of event (sec)	7.95	4.54	1.05	0.313	35
	Day Avg. ASEL	90.17	87.57	0.15	0.699	35
Off-river	Number of overflights	34.77	55.45	1.22	0.274	71
	L _{MAX}	95.99	106.82	3.59	0.062	71
	ASEL	87.67	95.69	3.54	0.064	71
	Duration	5.58	6.97	1.77	0.188	71
	Day Avg. ASEL	83.30	89.06	1.68	0.200	71

We also assessed the effects of aircraft noise on nest fate by assigning a disturbance level to each drainage each year based on ANM data, and then assigning an exposure level to all nests of

known fate that occurred in those drainages. When stratified by disturbance level, there were consistent trends indicating that nests in the high disturbance category had higher failure rates than did nests in the moderate or low disturbance categories, and this was particularly evident for off-river nests (Figure 10.3). For example, off-river nests in low disturbance drainages had a nesting success of 80%, whereas off-river nests in the high disturbance drainages had a nesting success of 63%. When evaluated statistically (*chi square*), however, none of these differences was even marginally significant ($p > 0.20$; Table 10.5).

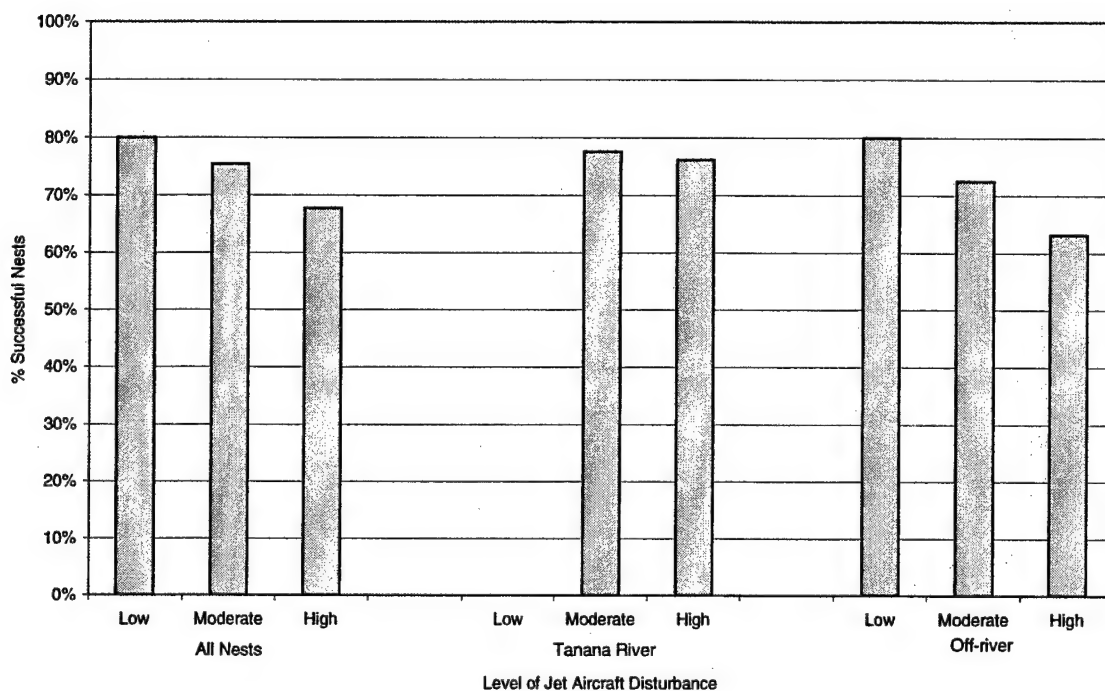


Figure 10.3. *Percentage of successful Peregrine Falcon nests exposed to different levels of jet aircraft disturbance in areas used for military training exercises, east-central Alaska, 1995–1997.*

Table 10.5 *Number of nests by fate and chi square statistics for Peregrine Falcons nesting in low, moderate, and high disturbance areas¹ used for military jet aircraft training exercises, east-central Alaska, 1995–1997.*

Sample	Nest Fate	Disturbance			χ^2 test statistic	p value
		Low	Moderate	High		
All Nests (n = 227)	Successful Failed	40 10	89 29	40 19	2.24	0.32
Tanana River (n = 88)	Successful Failed	0 0	52 15	16 5	0.18	0.89
Off-river (n = 139)	Successful Failed	40 10	37 14	24 14	3.08	0.21

¹ Each drainage and nest in the study area was classified for disturbance based on noise monitoring at a subsample of nests; nests with <0.1 flights/day were classified as low disturbance, 0.1–0.5/day were moderate, and >0.5/day were high.

Productivity

We used data from the ANM nests and regression models to assess whether there was a predictable dose/response relationship between the number of young produced/total pair (range 0-4) and noise exposure (Table 10.6). Of the 15 models tested, all but one had a negative slope, indicating that productivity decreased as noise exposure increased. Notwithstanding, none of the models was even marginally significant at $p > 0.10$. Models for potential exposure and daily average SEL were plotted, and, as was the case for analyses of nesting success, potential exposure appears to be the better predictor of peregrine response (Figure 10.4).

Table 10.6 *Linear regression models evaluating the effects of noise from jet aircraft on the productivity (number of young/ total pair) of nesting Peregrine Falcons in areas used for military jet aircraft training exercises, east-central Alaska, 1995-1997.*

Sample	Dosage Parameter	R^2	Slope	Intercept	p value	n
All nests	Number of overflights ¹	0.014	-0.003	2.12	0.223	106
	Duration of event	0.000	-0.003	2.04	0.888	106
	L_{MAX} ²	0.004	-0.004	2.42	0.539	106
	ASEL ³	0.001	-0.003	2.31	0.709	106
	Daily Average ASEL ⁴	0.002	-0.004	2.36	0.627	106
Tanana River	Number of overflights	0.031	-0.007	2.38	0.315	35
	Duration of event	0.005	-0.012	2.08	0.694	35
	L_{MAX}	0.010	0.008	1.40	0.573	35
	ASEL	0.028	-0.017	0.58	0.335	35
	Daily Average ASEL	0.008	-0.008	1.46	0.611	35
Off-river	Number of overflights	0.001	-0.002	2.02	0.384	71
	Duration of event	0.014	-0.040	2.18	0.331	71
	L_{MAX}	0.019	-0.009	2.79	0.312	71
	ASEL	0.018	-0.011	2.95	0.268	71
	Daily Average ASEL	0.016	-0.010	2.83	0.286	71

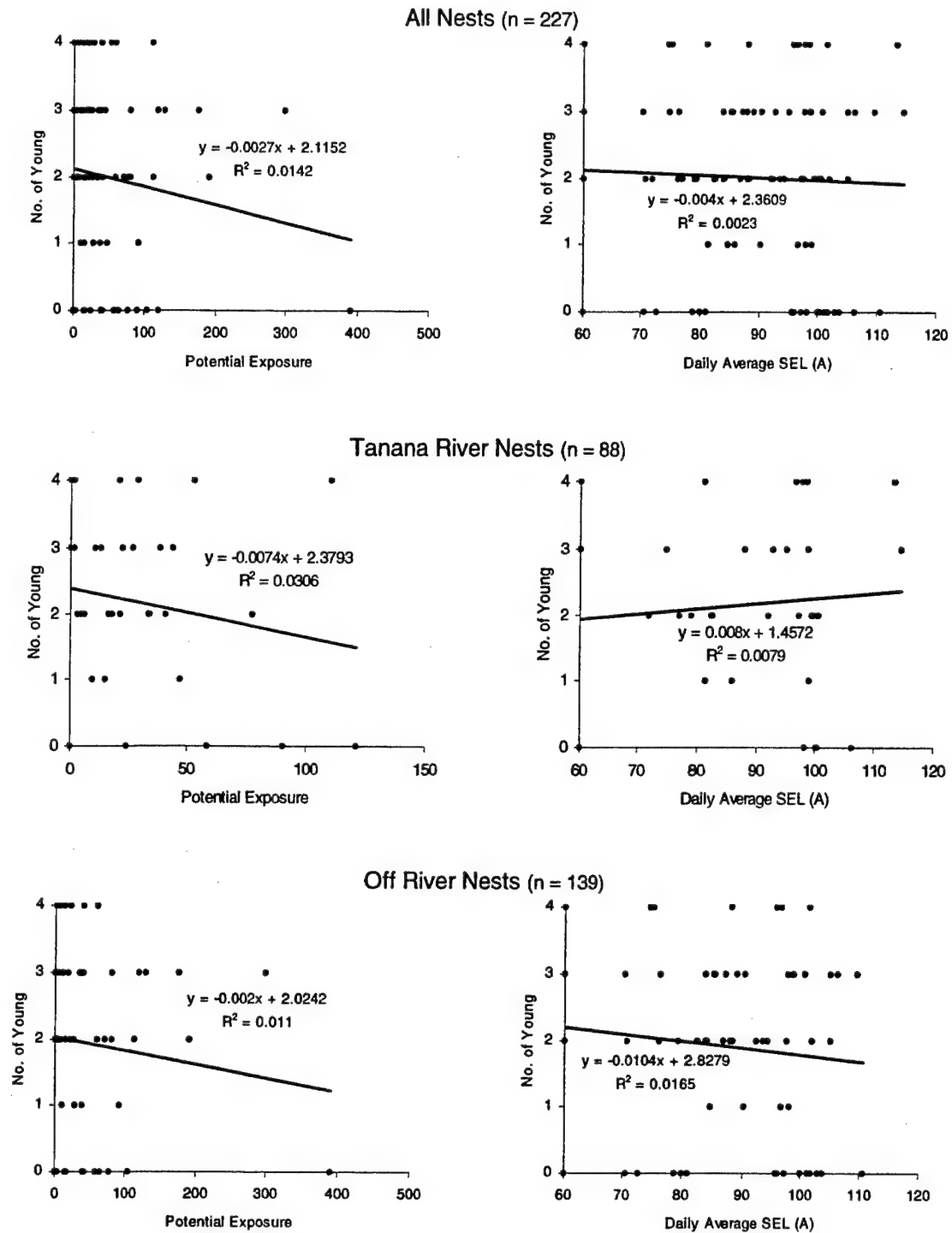


Figure 10.4 *Linear regression models evaluating the effects of noise exposure from military jet aircraft on nesting Peregrine Falcons, east-central Alaska, 1995–1997. Daily average sound exposure level (SEL) is a time-averaged measure of the frequency and intensity of noise events at peregrine nest sites, and potential exposure is a standardized measure of the number of aircraft overflights experienced by a nesting pair during the nesting season.*

The effects of aircraft disturbance on productivity also was assessed (ANOVA) by comparing mean number of young/total pair and mean number of young/successful pair among the previously described disturbance categories (Table 10.7 and Figure 10.5). For all nests, the highest productivity was achieved in the moderate disturbance category, while productivity in the low and high categories was nearly identical. These slight differences among disturbance categories were not statistically significant ($p = 0.46$). On the Tanana River, productivity was nearly identical in the moderate and high disturbance categories (no nests were classified as low disturbance), and again there was no significant difference between disturbance categories ($p = 0.74$). Although there was lower productivity in the high disturbance category than in either the low or moderate disturbance categories for off-river nests, these differences were not significant either ($p = 0.30$). Still, productivity of off-river nests in high disturbance areas was substantially less (1.4 young/total pair) than that recorded for Tanana River nests in high disturbance areas (2.1 young/total pair).

Table 10.7 *Comparisons (ANOVA) of the mean number of young produced at Peregrine Falcon nests experiencing low, moderate, and high disturbance levels in areas used for military jet aircraft training exercises, east-central Alaska, 1995–1997.*

Sample	Disturbance			<i>F</i>	<i>p</i> value	<i>n</i>
	Low	Moderate	High			
Total pairs						
All nests	1.8	2.0	1.7	1.04	0.456	227
Tanana River	-	2.0	2.1	0.22	0.742	88
Off-river	1.8	1.8	1.4	1.23	0.295	139
Successful pairs						
All nests	2.3	2.6	2.5	2.19	0.115	169
Tanana River	-	2.6	2.8	0.62	0.434	68
Off-river	2.3	2.5	2.3	1.38	0.255	101

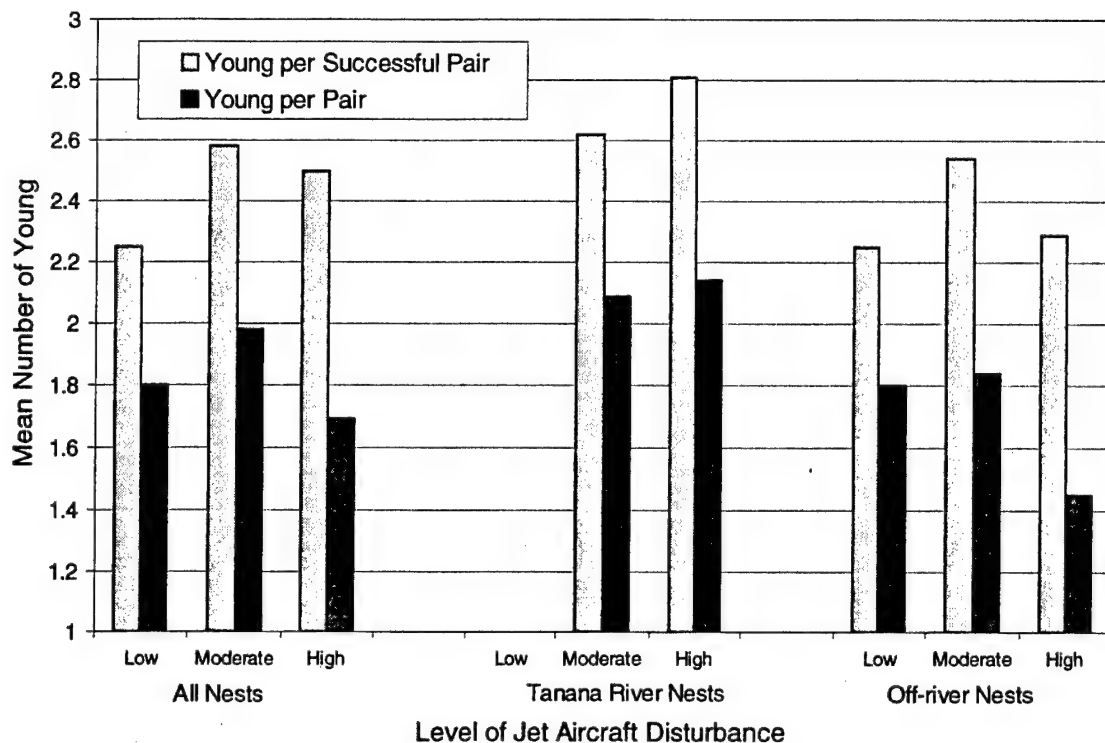


Figure 10.5. Mean number of young/successful pair and /total pair of nesting Peregrine Falcons exposed to different levels of jet aircraft disturbance in areas used for military training exercises, east-central Alaska, 1995–1997.

Analysis of the number of young/successful pair indicated that there was no statistical relationship ($p > 0.10$) between disturbance and the number of young produced at successful nests (Table 10.7 and Figure 10.4). For all 3 comparisons (all nests, Tanana River nests, and off-river nests), successful pairs in high disturbance areas produced more or comparable numbers of young than did pairs in low disturbance areas.

DISCUSSION

Nesting Success and Productivity

Nesting success in our study area during 1995–97 generally was higher and varied less from year-to-year than did rates recorded in other monitoring areas in interior Alaska. Nesting success ranged from 71–77% in our study area during 1995–97, for example, while during the same period it ranged from 69–88% on the Charley River (McIntyre 1996), from 63–85% on the Porcupine River (USFWS, unpublished data), and from 61–70% on the Yukon River (USFWS, unpublished data).

Productivity in our study area during 1995-97 also exceeded that recorded for other monitoring areas during the same period. Productivity ranged from 1.9-2.1 young/total pair in our study area during 1995-97, while during the same period it ranged from 1.9-2.0 on the Charley River (McIntyre 1996), from 1.4-1.9 on the Porcupine River (USFWS, unpublished data.), and from 1.4-1.9 on the Yukon River (USFWS, unpublished data). Although disturbance was not monitored in those other areas, these areas generally are more remote and probably less disturbed by military aircraft than our study area, with the possible exception of the Yukon River.

Noise Exposure

Levels of exposure to jet aircraft at individual nests ranged from no exposure to sites that potentially were overflowed nearly 400 times during the nesting period. The average overflight had an ASEL of 100.7 dBA, which is the approximate noise output of an F-15E at a slant distance of ~190 m (570 ft) (85% rpm, 450 knots airspeed; USAF Computer Program Omega 10.5). A-10s, which probably are the most ubiquitous aircraft in the MOAs, are considerably quieter than F-15s and would have to pass within ~80 m (250 ft) to generate noise levels exceeding 100 dBA (5333 NF, 325 knots airspeed; (USAF Computer Program Omega 10.5). Most of the other aircraft that use the air space (e.g., F-16s) generate noise levels that are substantially greater than A10s, but less than F-15s.

Anything over 100 dB is considered "very loud" (MOA EIS 1995); therefore, it is readily apparent that many of the nesting peregrines in our study area were subjected to both frequent and loud noise from passing jet aircraft. An unknown portion of these overflights also undoubtedly provided a visual stimulus to the birds.

Effects of Noise on Nesting Success and Productivity

Nesting Success

Although nesting success for our study area generally fell within the range of values for interior peregrine populations, our results do indicate that jet aircraft overflights might be adversely affecting nesting success of Peregrine Falcons. For ANM nests, there were consistent trends and significant test results that indicated that pairs that failed in their nesting attempt had greater exposure to jets and noise. Because these nests were monitored remotely, we do not know the exact mechanism of nest failure, but most evidence suggests that nests simply were abandoned during or before egg-laying: eggs or barren ledges regularly were recorded, whereas dead young were only identified at 3 of 59 failed sites. Although observers monitoring nests during overflights detected subtle effects of jet overflights on Peregrine Falcon parental behavior, no

panic flights by incubating or brooding adults, which might lead to egg or chick losses, were recorded (see Chapter 6).

Interestingly, nesting success did not differ greatly between disturbance categories for nests on the Tanana River, whereas it did for off-river nests. In addition, nesting success for Tanana River nests in high disturbance conditions was 13% higher than that recorded in high disturbance conditions at off-river sites (76 vs. 63%). These results suggest that there may be important differences either in the quality of Tanana River and off-river nesting habitats and/or differences in the peregrine populations between the two sites. Habitat differences could be related to prey abundance and availability. Along major drainages like the Tanana, there are substantial summer resident duck, shorebird, and gull populations that are important prey species for peregrines (Hunter et al. 1988; Chapter 10). These drainages also are major migration corridors for waterfowl and passerines (Kessel 1984). The off-river drainages are, by definition, smaller water courses that generally do not support waterbird populations as large or diverse as major drainages. Consequently, peregrines at off-river sites may be forced to travel farther to acquire adequate resources, and, therefore, energy available for breeding pairs to allocate toward reproduction may be different between the Tanana and off-river habitats.

Other researchers have found that food can affect nesting raptors and that disturbance effects can be more pronounced when food is in short supply. Carpenter (1993), for example, found that disturbance delayed breeding, reduced clutch size, and reduced breeding success in American Kestrels (*Falco sparverius*), particularly when the birds were energetically stressed due to low prey abundance. Lehman et al. (1993) also found lower nesting success of Prairie Falcons (*F. mexicanus*) in a military training area compared to reference sites; however, productivity throughout the region was low, and the authors suggested that these declines were related to reduced prey abundance.

Although cliffs at remote sites and along the Tanana are similar in geologic and physical properties, they do differ in relation to their general physiographic settings. That is, off-river sites typically are in uplands, whereas most Tanana River nesting cliffs are in lowlands (floodplain). Consequently, orographic influences of upland areas, such as increased precipitation and cooler temperatures with increasing elevation (Gallant et al. 1995), could result in harsher conditions at off-river nesting sites than at sites in the lowlands. Weather records from a lowland site (Fairbanks) and upland site (Eagle) provide some support that upland areas are cooler and receive more precipitation than lowland areas in the study area (Chapter 2).

Several researchers have shown that nesting success of peregrines can be related to weather. Mearns and Newton (1988) recorded the poorest success in the wettest years in a population of peregrines in Scotland. Olsen and Olsen (1989) found that rain may have curtailed nesting attempts at cliffs with poorly drained nest sites in Australia. Severe spring weather (snow and cold temperatures) drastically reduced nesting success in peregrines in northeastern Canada (Court et al. 1988, Bradley et al. 1997).

With respect to differences between peregrine populations on the Tanana River compared with off-river sites, it may be that, on average, the birds nesting along major drainages and using long-established nesting sites, are older, more experienced birds than birds that recently have colonized sites in off-river habitats (**Chapter 2**). Birds with a history of successful use of a particular nesting territory typically have greater nest site fidelity than do inexperienced breeders establishing new territories or occupying lower quality cliffs (Ratcliffe 1993). Mearns and Newton (1988) found that nesting success was higher at sites with long histories of use. Similarly, Court et al. (1989) found that peregrines breeding at territories for the first time did poorly. Considering that our data indicate that there is an expanding population in the off-river areas, and presumably greater numbers of younger birds and recently occupied cliff sites, similar phenomena may be occurring in our study area.

Differences in nesting success of peregrines on major drainages like the Tanana compared to pairs in off-river areas also may reflect different degrees of habituation or sensitization by these populations to jet aircraft. Habituation occurs when an organism learns to ignore commonplace stimuli that are not threatening, whereas sensitization entails increasing levels of response with repeated exposures (Shalter 1984). White and Thurow (1985) provided evidence for habituation of raptors to some human activities, but the degree to which peregrines habituate to aircraft probably is influenced by season, age, sex, previous breeding experience, weather, and prey availability (Ritchie 1987). Thus, comparable levels of disturbance may have differential effects on breeding pairs depending on the quality of their habitats and their age and experience. That is, inexperienced birds establishing new territories or energetically stressed birds may be more inclined to abandon a nest in the face of disturbance than would experienced birds in more favorable conditions.

Productivity

Our strategy in this study was to acquire adequate samples of nests from different habitats and under different environmental conditions to be able to isolate the effects of disturbance on productivity. Accordingly, we ran models for all nests, for nests on the Tanana River only, and

for off-river nests only, and none of these models indicated that there is a relationship between noise exposure and productivity of Peregrine Falcons. Interestingly, this analysis of the productivity of total pairs takes into account failed nests, and these results do not agree statistically with the significant results of the nesting success analysis, which showed that nests failed more frequently in high disturbance conditions. The productivity test results may not have been significant because the number of young/successful pair was unaffected by disturbance conditions; therefore, overall production of young in off-river areas still was relatively high. Despite a lack of statistical significance, the higher rate of nest failures in off-river areas with high disturbance conditions is reflected in the number of young/total pair, particularly when compared with nests in high disturbance conditions on the Tanana River.

An assumption for our analysis of productivity of successful pairs was that disturbance potentially can affect not only nest fate (i.e., success vs. failure), but also either clutch size or survivorship of young. Clutch size potentially could be affected by eggs being lost during disturbances due to panic flights, or if birds simply laid fewer eggs due to exposure to disturbance. Hamm (1967), for example, reported that egg production in poultry could be reduced after 3 or more days of exposure to aircraft noise. Whether data from a domesticated, indeterminate layer is applicable to a wild, determinate laying species, such as peregrines, is debatable, however. After hatch, unfledged birds could tumble from the nest during panic flights, or parental care for the young (e.g., provisioning rates) could be compromised due to repeated disturbances. Of course, factors other than disturbance (e.g., harsh storms, predators, food resources, and parental condition and experience) also can affect productivity. If eggs and or young were being lost incrementally, however, we would expect to see some successful pairs in disturbed areas with small broods. This was not the case in our study, however, because numbers of young produced at successful sites did not differ among disturbance categories. Furthermore, behavioral observations along the Tanana River indicated that intense or flight responses by peregrines to overflights were rare (see Chapter 6). Similarly, severe responses were uncommon in other studies of aircraft disturbance of Peregrine Falcons (Ritchie 1987, Ellis et al. 1991).

CONCLUSIONS

Considering that 84% of the ANM nests in our study area were overflowed by at least one aircraft during the nesting season and that productivity in our study area is relatively high and stable compared to other monitoring areas in interior Alaska, it follows that current levels of military training exercises have not had major population-level effects on peregrines breeding in the region. Furthermore, the slightly higher nesting success and productivity of nests with ANMs

than our larger sample of nests indicates that our intrusions into nesting territories to deploy and retrieve ANMs did not adversely affect nesting activities.

We provide evidence that indicates that nesting success in off-river sites is related negatively to jet aircraft noise. We suspect that disturbance effects may be greater for off-river pairs because of lower quality habitats, orographic features of the landscape, and/or the age and experience of the breeding pairs in this expanding population. Nesting success in these off-river sites was similar to or greater than other monitoring areas in interior Alaska, however, which suggests that population-level effects of disturbance are relatively minor.

Productivity of young in our study area was high, and pairs that hatched young raised broods that were similar in size to pairs on other interior rivers of Alaska. Productivity of successful pairs did not appear to be affected by disturbance. Thus, it follows that the mechanism by which military jet aircraft disturbance affects Peregrine Falcons in our region is by nest abandonment, rather than by attrition of young. These results suggest to us that disturbance effects vary inversely with the experience and parental investment of the individual breeding pairs. In one extreme, inexperienced pairs that are prospecting for nesting territories in marginal habitats may abandon nesting attempts before or shortly after eggs are laid if disturbed. At the other extreme are established pairs with long histories of breeding at traditional territories, and for these pairs, disturbance from jet aircraft appear to have little or no affect on nesting success or productivity.

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